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THE EFFECTS OF POLLUTION CONTROL ON THE NONFERROUS METALS INDUSTRIES

ALUMINUM

Part II

Structure of the Industry

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CHARLES RIVER ASSOCIATES INCORPORATED

THE ECONOMIC EFFECTS OF POLLUTION CONTROLS ON THE NONFERROUS METALS INDUSTRY: ALUMINUM

Prepared for
the Council on Environmental Quality

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PREFACE

This report on the economic effects of pollution controls on the aluminum industry has been organized into three parts comprised of eight chapters. The three parts can be read separately or in conjunction with one another. Part I summarizes the contents of the succeeding two parts, providing a broad profile of the aluminum industry and outlining the economic effects of pollution controls on the industry. The important points and conclusions of the full report are contained in the first part, with greater detail and analysis in the following two parts.

Part II comprises separate chapters on:

- Trends in supply and the technology of production
- Consumption
- Structure of the industry
- Prices
- Government policies
- The aluminum industry in the United States

Part III is our detailed analysis of the economic effects of imposing pollution controls on the aluminum industry.

Much of the information contained here was first published in Charles River Associates Incorporated, *An Economic Analysis of the Aluminum Industry* (Cambridge, Mass., March 1971), which we prepared under contract with the General Services Administration. Data presented in this report if not otherwise attributed is taken from our GSA report.

PART II

Chapter 2

TRENDS IN SUPPLY AND TECHNOLOGY OF ALUMINUM PRODUCTION

Primary aluminum production is divided into three stages: bauxite mining, alumina production, and the reduction of alumina to aluminum. The last stage accounts for about two-thirds of the average cost per ton of primary aluminum at an integrated aluminum complex. The three stages in production tend to occur in different physical locations and have different technologies and cost functions.

Bauxite

On an average cost basis, bauxite mining is the least costly of the three stages of aluminum production; it is also the least capital intensive and most flexible. Although between 5.5 and 6 short tons of bauxite are consumed in the production of 1 short ton of aluminum, the average cost of mining and shipping bauxite from a high-quality deposit represents only about 8 to 10 percent of the delivered price of aluminum ingot.

In nature aluminum is invariably combined with other elements. There are three known hydrated aluminum oxide minerals with fairly well defined geographic distribution. *Gibbsite*, the only naturally occurring form of aluminum trihydrate ($Al_2O_3 \cdot 3H_2O$), contains 65.4 percent alumina and 34.6 percent water. *Boehmite* and diaspore (alpha monohydrate, $Al_2O_3 \cdot H_2O$) each contain 85 percent alumina and 15 percent water. Diaspore is not used to produce aluminum commercially.

Bauxite is classified into Jamaican, Surinam, and European types. The first contains both trihydrate and monohydrate, the second trihydrate only, and the third contains all grades but is mostly boehmite (monohydrate).

From 1947 to 1970 noncommunist world production of bauxite grew from 6.0 million short tons to 54.4 million. In 1947, Surinam, Guyana, the United States, and France accounted for about 91 percent of total bauxite supply. Since then production has grown steadily in Surinam, Guyana, and France, but there has been little growth in the United States. Three major new producers have begun bauxite mining on a large scale: Jamaica (1952), Guinea (1952), and Australia (1963). By 1970 Jamaica, Australia, Surinam, Guyana, and France accounted for about 68 percent of noncommunist world bauxite production.

NONCOMMUNIST WORLD BAUXITE PRODUCTION
(Thousands of Short Tons)

Country	1947	1955	1960	1965	1970
Jamaica	--	2,963	6,436	9,538	12,000
Surinam	1,917	3,376	3,809	4,807	6,638
Australia	5	8	78	1,308	10,350
Guyana	1,522	2,728	2,768	3,218	4,750
France	750	1,647	2,279	2,937	3,363
Yugoslavia	97	872	1,130	1,735	2,314
United States	1,346	2,003	2,238	1,853	2,273
Guinea	NA	544	1,519	1,764	2,750
Dominican Republic	--	--	759	985	1,200
Noncommunist World	6,040	15,901	24,798	33,679	54,362

Sources: *Minerals Yearbook* (1952); *Metal Statistics* (Frankfurt, 1949-1969); *Metal Statistics* (U.S., 1970).

Bauxite Reserves

Estimated world bauxite reserves were approximately 6.0 billion short tons in 1965, with marginal and submarginal resources of nearly 9.8 billion short tons. Known reserves in Australia were 23.1 million short tons in 1950, 672.0 million short tons in 1958, and 2,204.6 million short tons in 1965. At that time Australia had by far the greatest bauxite reserves, with 38.3 percent of noncommunist commercial reserves, followed by Guinea (23.0 percent), Jamaica (11.5 percent), and Surinam (3.0 percent).[1] The data on bauxite reserves indicate that there is no danger of a bauxite shortage developing within the next several decades, and known marginal resources guarantee bauxite supplies well into the next

[1]The bauxite reserves in the Soviet Union are estimated at approximately 300 million tons.

century.[1] The location of new bauxite discoveries, both proven reserves and potential resources, suggest a likely geographic shift in the location of future bauxite and alumina production with Australia and Africa becoming relatively more important producers.

An important feature of the size and distribution of bauxite reserves is that despite their ubiquity and the large size of known commercial deposits, the number of easily accessible deposits with high bauxite content (greater than 50 percent) is small. As a result the number of bauxite deposits of commercial value is relatively few. Thus, while the established producers have ownership over bauxite reserves sufficient in size to supply industry output of aluminum for many decades in the future, the supply of bauxite for new producers is very limited.

Bauxite Mining

Approximately 90 percent of total noncommunist world bauxite production is mined by open-pit methods. Bauxite mining in Europe is predominately underground, while bauxite production in the rest of the world is almost always extracted by surface mining. After extraction, the bauxite is generally crushed, dried, and beneficiated before shipment to an alumina plant.

The most important economic distinction between open-pit and underground methods is the time period required to begin production and the ease with which the rate of production can be varied. Open-pit mines can

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[1]Aluminous material of less than 30 percent Al_2O_3 is found in large quantities throughout the world. Estimated resources of 27 percent Al_2O_3 in the United States alone is 600 billion short tons.

respond readily to variations in demand with little effect on average cost, as production can be increased or decreased simply by using more or less equipment. Expansion of output from an underground mine, however, would generally require the digging of additional shafts, which could take a substantial amount of time.

Aluminum is unique among nonferrous metals industries in that the mining of the ore in general represents a fairly small percentage of total costs. The composition of bauxite mining costs, however, has had a noticeable effect on the location of alumina plants. Transport costs tend to be 25 to 50 percent of the delivered cost of bauxite in the United States, although the amount varies with the source of the bauxite. The costs of shipping bauxite and alumina are nearly equal per ton mile, but as the aluminum content of alumina is approximately twice that of bauxite, transport costs (although not necessarily total costs) may be substantially reduced by locating alumina plants near bauxite mines.

Bauxite mining is not necessarily a large-scale, capital-intensive operation requiring a large initial investment. Generalizations in this area are difficult because the nature and cost of a bauxite project depends on the geological characteristics and geographical location of the deposit. If a deposit is shallow, the minimum efficient scale of operations may be fairly small; if the deposit is deep, however, the minimum efficient scale may be very large. Similarly, if the deposit is located in an inaccessible area it may be necessary to build roads, port facilities, and other infrastructure, which would result in a very large initial capital investment. Initial capital costs may

range from as low as $10 million to as high as $300 million, and the annual capital cost per ton may range from less than $2 to over $6.

Scale economies in bauxite mining are also fairly important. The efficient scale of a bauxite mining operation depends heavily on location and site characteristics. In addition to economies imposed by the nature of the deposit, scale economies also stem from the auxiliary facilities such as electric power and transportation, which have to be provided at typically remote mining locations.

Known capacities of 26 operating bauxite mines in 1969 ranged from 83,000 to 6,612,000 short tons per year. Fifteen mines had capacities of over 1 million tons and an additional four mines had capacities between 500,000 and 1,000,000 tons. The total capacity of these 19 mines was 45.186 million tons, or about 81 percent of known noncommunist bauxite production capacity in 1969 of 55.565 million tons.[1] It appears that a capacity of well over 1 million tons may frequently be required for efficient mining of a bauxite deposit.

The cost information discussed so far refers to established bauxite mines, usually owned and operated by the major integrated firms. The important consideration for a new entrant, of course, is the cost of exploring, developing, and mining a new deposit. As the quality of marginal bauxite deposits is substantially lower than the quality of bauxite deposits currently being exploited, it is difficult to assess the cost disadvantage faced by a new producer. It may be fairly substantial. For example, if the bauxite content of

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[1]Complete data are in our March 1971 report to GSA.

a marginal deposit is 35 percent instead of 50 percent, the average cost per ton of beneficiated bauxite may be double that of the richer deposit.

Alumina

The bauxite received at alumina plants is a mixture of aluminum hydrates, silica, titania, water, and some other impurities. In the alumina stage impurities are separated from the aluminum hydrates and these hydrates reduced to 99 percent pure alumina (Al_2O_3).

The Bayer process, invented in 1888, is still the only commercial process for producing alumina. The conventional Bayer process is used for high-grade bauxite containing less than 10 percent silicon. The American Bayer process is used for treating gibbsite and the European Bayer process is used for boehmite. These three processes are similar in nature, but use different equipment and procedures.

According to a number of sources, there are substantial scale economies in alumina production up to at least 330,000 tons per year,[1] and one source has estimated the minimum efficient scale for U.S. plants to be about 600,000 short tons per year.[2] Two tons of alumina are required to produce one ton of aluminum.)

As with bauxite mining, it is difficult to generalize about the total initial capital investment required

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[1]See *Studies in Economics of Industry 2: Pre-Investment Data for the Aluminum Industry*, ST/CID/9, United Nations, (New York, N.Y., 1966).

[2]Alexander Karim, "Economics and Directional Growth in the Aluminum Industry," *Proceedings of the Council of Economics*, American Institute of Mining, Metallurgical and Petroleum Engineers, Inc., Annual Meeting, New York, February 25-29, 1968, pp. 256-297.

from an alumina plant. It appears from UN data that the minimal investment for an efficient plant is about $43 million (in 1966 prices). However, this figure is contingent on the nature of associated facilities. With a growing trend to locate bauxite and alumina facilities together, it may be most meaningful to consider the capital cost of a bauxite-alumina complex, where the initial capital investment may be as high as $200-300 million.[1]

Using 1966 data the average cost of production at an alumina plant with an annual capacity of 330,000 short tons (close to the optimal size), was estimated to be about $59 per short ton, broken down as follows:[2]

Input	Quantity	Cost (1966 Dollars)
Bauxite	2.1 tons	$16.80
Caustic Soda	80 kg NaOH	5.10
Steam	2 tons	3.30
Electric Power	200 kwh	0.80
Fuel for Calcination	130 liters fuel oil	2.60
Labor	3 man hours	7.50
Maintenance	--	3.00
Capital cost:	$43 million	
Depreciation		9.00
Interest		7.20
Miscellaneous		3.70
TOTAL		$59.00

Thus, short-run variable costs were about $42.80 per ton (including bauxite costs), while fixed costs were

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[1]According to *Metal Bulletin*, capital costs of this magnitude have been reported for recent projects in Australia and Jamaica.

[2]*Pre-Investment Data, op. cit.*, p. 10.

about $16.20 per ton. In 1970 dollars, total average costs would be about $72.00 per ton and short-run variable costs would be about $52.00 per ton.

Historically, alumina plants have usually been located near aluminum smelters, although the trend in recent years is for alumina plants to be located near the bauxite mines. Of the seven major alumina plants recently constructed, five were located relatively near bauxite mines.[1]

Depending on the nature of the ore and the type of process used, between 2 and 3 tons of bauxite are used per ton of alumina. As the cost of transporting a ton of alumina is about the same as the cost of transporting a ton of bauxite, this suggests it would be more efficient to locate alumina capacity near the bauxite source. According to one recent study, however, "All in all, there seems to be no compelling case for the location of alumina plants either at ore site or smelter."[2] The recent tendency to construct alumina plants in the countries where bauxite is mined can probably be explained by political pressures tipping the balance in a situation in which the producers would otherwise be fairly indifferent.

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[1] *Engineering and Mining Journal*, Vol. 169, No. 2 (February 1968), pp. 102-103.

[2] Sterling Brubaker, *Trends in the World Aluminum Industry*. (Baltimore: Johns Hopkins Press for Resources for the Future, Inc., 1967), p. 153.

Aluminum

Production of aluminum in the noncommunist world has grown more than eightfold since World War II; between 1947 to 1970 total production increased from 1.053 million tons to 8.822 million tons. At the beginning of this period the United States and Canada were by far the largest producers, accounting for 55 and 28 percent of total noncommunist production in 1947. Production in the United States and Canada increased rapidly but their shares of total production fell to 45 and 12 percent in 1970. Other important producers in 1970 were Japan (9 percent), Norway (7 percent), France (5 percent), and West Germany (4 percent).

NONCOMMUNIST WORLD PRODUCTION OF PRIMARY ALUMINUM
(Thousands of Short Tons)

Country	1947	1955	1960	1965	1970
United States	571.8	1,565.9	2,014.7	2,754.7	3,976.1
Canada	299.1	607.8	762.1	830.6	1,061.0
Japan	3.0	63.4	146.8	324.0	807.8
Norway	23.9	79.5	188.2	303.8	584.4
France	58.9	142.2	259.3	375.4	420.0
West Germany	--	151.1	186.2	258.4	341.0
Other Noncommunist	95.9	245.9	430.8	773.6	1,369.5
World Total	1,052.6	2,855.8	3,988.1	5,620.5	8,822.1

Sources: *Minerals Yearbook; Metal Statistics* (Frankfurt); *Metal Statistics* (U.S.).

Aluminum is electrolytically produced from alumina by the Hall-Heroult process, developed in 1886. Two

similar types of plants are in commercial operation currently, using either the prebaked or the Soderberg anode system.[1] New processes are constantly being experimented with, but none have yet been demonstrated to be commercially superior to the Hall-Heroult system.[2]

An aluminum smelter is comprised of one or more potlines, each of which contains about 125-150 electrolytic cells. The rate of production of an aluminum reduction plant depends on the number of potlines in use. It is possible to switch on or off an individual line or even a segment of a line. Variable costs are apparently proportional to the number of potlines in operation; average variable costs apparently are somewhat increased if fractions of potlines are in operation. That is, it is less than twice as expensive to operate a complete potline than it is to operate half of a potline.

There are significant economies of scale in aluminum reduction, although the optimal size of operation (measured in equivalent units of aluminum production) is apparently somewhat smaller than that for an alumina plant. According to a U.N. study, the most efficient scale is about 100,000 tons per year.[3]

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[1] In prebaked anode plants carbon anodes are prepared separately and inserted into the electrolytic cell. In Soderberg (self-baking anode) plants a carbon mix is added to a steel shell permanently emplaced in the electrolytic cell.

[2] Two new processes involve direct reduction of bauxite. Small pilot plants are in operation, but large-scale commercial success has not yet been achieved. See below.

[3] *Pre-Investment Data, op. cit.*, p. 18.

The capital investment required for an aluminum smelter is quite large relative to most other industries. Investment costs in Europe are somewhat smaller than in North America, while investment costs in Scandinavia are somewhat greater. Capital costs in developing countries tend to be about 20 percent greater than capital costs in developed countries.[1] The following investment costs have been estimated for plants of different sizes in the United States:[2]

Annual Plant Capacity (Tons)	Prebaked Plant (Millions of 1966 Dollars)	Soderberg Plant (Millions of 1966 Dollars)
20,000	20-26	18-24
50,000	38.5-52.5	35-50
100,000	65-85	65-85
200,000	100-140	110-150

It appears therefore that construction of an aluminum plant of optimal size requires an investment of at least $65 million, and depending on the circumstances, the cost may be as high as $150 million.

Investment costs in the postwar period range from a low of $9.9 million for a 12,000-ton plant in India in 1951 to a high of $605 million for a 550,000-ton plant in Canada in 1951. The lowest investment cost reported for a plant of optimal scale (100,000 tons and over) was $74.8-79.9 million for a 112,500-ton plant in the United States in 1956.

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[1] *Ibid.*, p. 13.

[2] *Ibid.*, p. 11.

An important feature of an aluminum smelter is that there is no great penalty in terms of average cost of production for constructing a plant of smaller than optimal size. The average cost of production of a 20,000-ton plant is only 10 percent greater than that of a 100,000-ton plant. Furthermore, the cost of expanding existing plants is usually considerably less, per ton of annual aluminum capacity, than that of new plants.[1] It is quite common for firms to construct small aluminum smelters and to expand capacity gradually over a period of years. This is also often true of the major integrated firms. For example, Alcoa's smelter at Evansville, Indiana was constructed in 1960 with a capacity of 35,000 tons and by 1966 it had a capacity of 175,000 tons. Consolidated Aluminum (a subsidiary of Alusuisse) initiated production in the United States in 1963 with a plant at New Johnsonville, Tennessee with an annual capacity of 20,000 tons; by 1966 the capacity of this plant was 106,000 tons.

Smelting Costs

Just as bauxite is the major cost element in the production of alumina, alumina is in turn the major cost item in the production of aluminum. The variable costs of aluminum production are, again, much larger than the fixed costs. A breakdown of the input costs of an "optimal size" 100,000-ton per year Soderberg plant in the United States was estimated in 1966 to be as follows:[2]

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[1] *Ibid.*, p. 13.

[2] *Pre-Investment Data, op. cit.*

Input	Quantity (Per Ton of Aluminum Output)	Cost (1966 Dollars per Ton of Aluminum)
Alumina	2 tons	$118
Fluorides	35 kg of cryolite	25
Carbon	560 kg	25
Operating and Maintenance Supplies	--	18
Power	17.5 kwh	25
Labor	14 man hours	42
Miscellaneous	--	38
Capital Charges:		
Depreciation	$72 million	53
Interest	15 percent	48
TOTAL		$418

Short-run variable costs (including alumina) were about $300 per ton (about $0.15 per pound) and fixed costs were about $111 per ton. In 1970 dollars, total average costs would be about $508 per ton (or about $0.25-0.26 per pound) and short-run variable costs would be about $373 per ton (or about $0.18-0.19 per pound).

Location of Aluminum Smelters

The two most important factors affecting smelter location are power costs and access to consuming markets. Historically, smelters have been constructed in areas with low power costs and easy access to major industrial markets. More recently, low-cost power has become increasingly scarce and the most important factor affecting the location of many new smelters is access to major markets.

As aluminum production is very capital intensive, there is little likelihood that smelters will be built

in underdeveloped countries. For example, one study found that there is a significant cost disadvantage in these countries.

Thus, under normal conditions, one would expect new smelter capacity serving the U.S. market to be located in the United States. It is quite possible, however, that a moderate increase in costs of production in the United States could induce location of smelters in other industrialized nations. The current tariff on aluminum ingot is $0.01 per pound (plus the 10 percent surcharge) and transport costs are between $0.005 and $0.015 per pound, as the following data attest (dollars per metric ton):

British Columbia - Australia	$25.00
Quebec - Argentina	30.00
British Columbia - Japan	25.00
Norway - New York	7.15
Quebec - Holland	18.50
Quebec - United Kingdom	17.80
Norway - United Kingdom	10.00

Thus, an increase in United States aluminum production costs in excess of $0.02-0.03 per pound would cause many new smelters, especially those serving coastal markets, to be located abroad, especially in Norway, Canada, or Japan.

Short- and Long-Run Cost Functions

Several conclusions about the short-run and long-run cost functions for producing aluminum can be drawn from a knowledge of its technology. First, aluminum production can respond quite rapidly to changes in market

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[1] Brubaker, *op. cit.*, p. 159.

conditions. To reduce output at a particular plant it is necessary only to shut down a potline or a portion of a potline. This can be accomplished rapidly and with little detriment to the other operations of the plant.

Second, average variable cost (and therefore short-run marginal cost) at a given plant is virtually constant as output rises until output begins to approach rated capacity. At this point the marginal cost of production begins to rise rapidly.[1]

Third, the long-run average cost (and therefore the long-run marginal cost) of production is relatively constant even for fairly small increases in output. Increases of output of about 100,000 tons can be accomplished with little change in cost by constructing new plants, and smaller increases can be obtained with little or no change in average cost by adding potlines or even individual cells to existing plants.[2]

Costs of Integrated Aluminum Production

An efficient integrated aluminum complex must be large enough to support an alumina plant producing at least 330,000 tons per year of alumina (the minimum

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[1]It should be noted that the capacity of a plant is not an unambiguous figure. Plants can operate at more than 100 percent capacity, and in periods of shortage occasionally have produced at more than 100 percent of capacity.

[2]Increases in prices of factor inputs as a result of increased aluminum production may alter these conclusions slightly, although such increases do not seem likely.

efficient size of an alumina plant). This indicates that bauxite production capacity must be at least 700,000 tons per year. Furthermore, the efficient scale of operations at some bauxite deposits may be well over 700,000 tons per year. In this case total capital requirements for an integrated project would be greater than the figures given below.

Using the data on capital costs provided earlier, the *minimal* investment cost of an integrated project would be in the range of $149-263 million, broken down as follows:

Plant	Cost per Ton (1966 Dollars)	Total Cost (Millions of 1966 Dollars)
700,000-ton bauxite mine	$ 8-90	$ 5.6-63.0
330,000-ton alumina plant	110-180	36.3-59.4
165,000-ton aluminum smelter	650-850	107.3-140.3
		$149.2-252.7

It should be emphasized that cost estimates are made for optimal conditions only, and the actual cost of a particular project may be several times greater than the estimates. For example, Peck estimated that the investment required for a new entrant to construct an integrated bauxite-alumina-aluminum complex would be $600-800 million in 1958 prices.[1] This estimate would place the cost of an integrated project at close to $1 billion in 1970 prices.

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[1]Merton J. Peck, *Competition in the Aluminum Industry 1945-1958.* (Harvard University Press: Cambridge, Mass., 1961) p. 170.

While the substantial scale economies in alumina production determine the minimal efficient scale of an integrated aluminum operation, the cost function of aluminum production is dominated by the aluminum reduction process, which accounts for fully two-thirds of average per ton costs of production. Bauxite production accounts for about one-twelfth and alumina production accounts for about one-quarter of total production. As a result, the short-run and long-run cost functions for an integrated aluminum plant are probably very similar to those of a nonintegrated aluminum smelter: in the short run, average variable costs and marginal costs are fairly constant up to capacity and increase rapidly as rated capacity is approached: in the long run average and marginal costs are relatively constant for a firm with access to commercial bauxite deposits.

A composite cost breakdown for an integrated aluminum complex could appear as follows:

Input	Quantity (Per Ton of Aluminum Output)	Cost (1966 Dollars per Ton of Output)	Cost (1970 Dollars per Ton of Output)
Bauxite	4.2 tons	$ 33.60	$ 40.99
Caustic Soda	160 kg	10.20	11.39
Steam	4 tons	6.60	7.89
Electric Power	17,900 kwh	62.60	66.82
Fuel Oil for Calcination	260 liters	5.20	6.20
Fluoride	35 kg	25.00	31.95
Carbon	560 kg	25.00	32.50
Labor	20 man hours	57.00	68.05 (64.27)[1]
Operating and Maintenance supplies	--	24.00	27.62
Annual Capital Cost			
Depreciation	--	71.00	81.72
Interest	--	52.40	83.14
Miscellaneous	--	45.40	52.03
TOTAL		$418.00	$506.53

[1]Adjusted for labor productivity improvement.

As the above figures indicate, capital costs constitute a fairly high percentage of average production costs -- in 1970 dollars the capital charges for one ton of aluminum are about $164.00 (or about $0.08 per pound), not including the capital cost of bauxite production, or about one-third of total costs of about $507 per ton (or about $0.25-0.26 per pound). In addition, a portion of the costs indicated under other headings (such as "miscellaneous" and "operating and maintenance supplies") are probably fixed in the short run. As a result, short-run average and marginal costs are substantially lower than long-run average and marginal costs.

Foreseeable Trends in Production Technology

Although there has been a steady increase in productivity over the past two decades in alumina and aluminum production, the basic processes used for manufacturing these products have been unchanged since the 19th century. The probable outlook for the next decade is that the prevailing raw materials and processes for producing aluminum ingot will continue to be used, with gradual improvements in efficiency.

Ways to produce aluminum directly from bauxite or some other aluminum-bearing material, have been sought with varying intensity since World War II. This search has recently gained new momentum. For example, National-Southwire is developing alunite deposits in Utah,[1] and several joint ventures have been issued mining leases

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[1] *Metals Week*, July 12, 1971.

on Federal oil shale lands in Colorado. The oil shale contains dawsonite, which is a source of alumina. A company involved in two of the ventures regards the lands involved as "a potential source of significant quantities of alumina within the continental U.S."[1] Various clays are expected to become competitive with bauxite, but not within the 1970 decade.[2]

On July 5, 1971, *Metals Week* reported that U.S. producers have become interested in a Mexican process for commercial production of alumina from alunite containing as little as 10 percent alumina. Three plants have been proposed of which one has financial backing at present. This plant will have an annual capacity of 33,000 tons of alunite, from which 5,500 tons of ammonium sulfate, 2,500 tons of potassium sulfate and 4,400 tons of alumina will be produced. Alumina from the first plant will be converted into aluminum salts, but calcinated alumina suitable for metallic aluminum will be a product of the additional plants.

Processes of direct reduction of either bauxite or some other material will be commercially used eventually, but not extensively within the next 20 years. Alcan and Péchiney have both discontinued their experimental efforts in this direction. Reynolds, which has a direct reduction plant in Richmond, Virginia, is counting on no more than 20 percent of its own metal's being produced in this manner by 1980.[3] Of the additional capacity scheduled to come

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[1] *Metals Week*, July 12, 1971.

[2] Bureau of Mines, *Mineral Facts and Problems*, 1970 edition

[3] *Ibid.*

on stream in the next five years, all appears to be based on the conventional technology. We can expect, however, that there will be improved control of cell operations, reduced electrical power requirements, and other reduction process improvements.[1]

[1]Federal Reserve Bank of San Francisco, *Aluminum: Past and Future.*

Chapter 3

CONSUMPTION OF ALUMINUM

Aluminum's distinguishing characteristics are its light weight, strength, and matural attractive appearance. In addition, many aluminum alloys possess the tensile strength of steel, while retaining the light weight of aluminum.

Before World War II the three largest markets for aluminum in the United States were the transportation industry, the electrical industry, and the cooking utensil industry. Since the war, aluminum used in building and construction has grown rapidly, and this application is currently one of the most important end uses for aluminum product shipments. By the early 1950's the new technology developed during wartime made its impact on the civilian markets. New alloys made fabrication easier, and as a result of a lower cost relative to competitive materials aluminum consumption in several new fields grew rapidly.

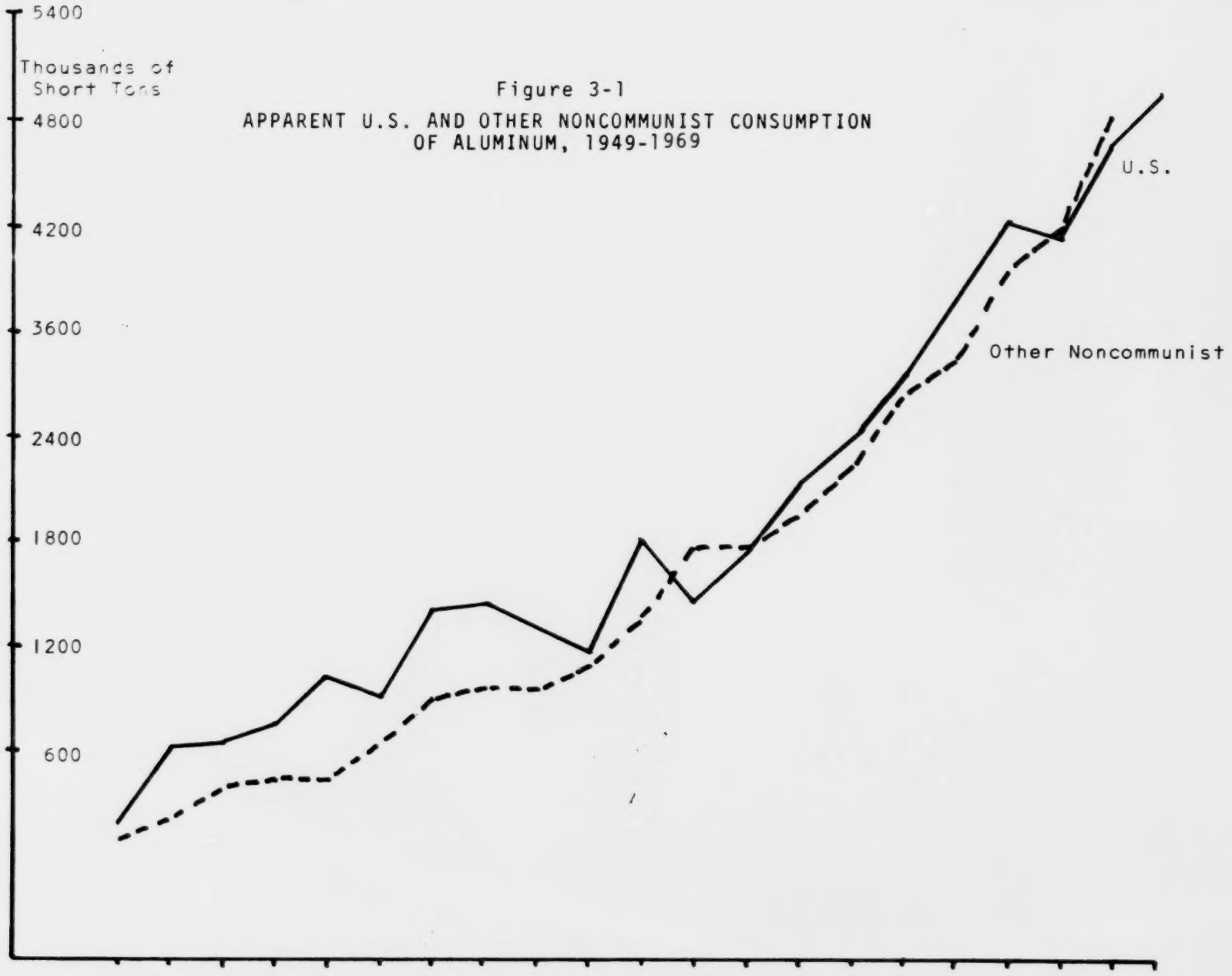
Aluminum consumption can be measured in several ways, depending on the stage in the production process at which the measurements are taken. Perhaps the most meaningful measurement is aluminum contained in shipments of fabricated products to consumers, which includes aluminum produced by both primary producers and secondary producers. In general, secondary aluminum shipments account for about 20 percent of total shipments.

Figure 3-1 shows U.S. and other noncommunist aluminum consumption, defined as aluminum contained in shipments of fabricated products to consumers, for the years 1949-1969. Consumption of aluminum in the noncommunist world grew very rapidly in the postwar period, increasing from 1.484 million short tons in 1949 to 10.710 million tons by 1969. The rate of growth has been somewhat uneven. Rapid growth from 1949 to 1956 was followed by declines in consumption in 1957 and 1958. Between 1958 and 1969 consumption increased steadily and rapidly, with the exception of a deceleration in growth in 1960. Between 1960 and 1969 consumption grew fairly steadily with an average annual rate of growth of about 10 percent.

The United States is by far the largest consumer of aluminum in the noncommunist world, accounting for about 46 percent of total consumption in 1969. The other important consumers are West Germany (8 percent), the United Kingdom (6 percent), and Japan (11 percent). As one would expect, the fastest growth in consumption has occurred in Japan. Between 1949 and 1969 aluminum consumption in Japan grew from 18,000 to 1,209,000 tons.

Figure 3-1

APPARENT U.S. AND OTHER NONCOMMUNIST CONSUMPTION OF ALUMINUM, 1949-1969



SOURCE: Metallgesellschaft, *Metal Statistics*, 1949-1968.

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CHARLES RIVER ASSOCIATES INCORPORATED

APPARENT CONSUMPTION OF ALUMINUM BY CONSUMERS OF FABRICATED AND SEMIFABRICATED PRODUCTS (Thousands of Short Tons)

	1955	1960	1965	1969
U.S.	1995.0	2058.0	3788 0	4909.0
Canada	99.1	121.0	209.7	281.9
West Germany	295.2	472.6	615.6	825.2
Belgium and Luxembourg	31.4	73.3	129.9	185.7
Netherlands	10.8	22.0	22.4	51.6
Italy	96.9	157.6	214.9	421.1
France	154.8	264.8	342.2	553.6
United Kingdom	440.7	535.5	595.4	675.0
European Economic Community	585.8	990.0	1325.0	2037.2
Japan	65.3	220.5	447.5	1209.0
TOTAL	3831.6	4861.1	7943.2	10710.2

SOURCES: *Metal Statistics* (Frankfurt, 1957-68); *Aluminum Statistical Review* (1970).

U.S. Shipments of Mill Products

The "users" of aluminum are generally firms that use semifabricated shapes (wire, rod, sheet, etc.) in their products. In a sense, then, the end products of the aluminum industry are the semifabricated products.

Most shipments to consuming firms are of semifabricated mill products; however, between 25 and 30 percent of the shipments are ingot. Mill product shipments consist of wrought products (rolled, extruded, and forced shapes) and castings (sand, permanent mold, and die castings). It should be noted that total

shipments of mill products as reported below are greater than consumption of primary aluminum because mill products contain both primary and secondary aluminum.

NET U.S. SHIPMENTS OF ALUMINUM
INGOT AND MILL PRODUCTS
(Thousands of Short Tons)

	1955	1960	1965	1969	1970
Ingot	602.7	804.3	1168.6	1525.0	1277.8
Sheet and Plate	672.3	694.1	1304.4	1856.0	1844.3
Foil	99.1	124.5	197.8	280.0	279.4
Rod, Bar and Forgings	90.1	71.5	128.0	155.0	129.3
Bare Wire	30.8	27.7	41.3	47.2	46.7
ACSR and Bare Wire	78.4	91.6	214.7	237.6	249.7
Covered Wire and Cable	19.8	30.2	64.7	125.0	130.1
Extruded Shapes	341.2	425.5	771.2	893.2	822.9
Tubing	46.4	43.1	88.1	94.6	88.3
Powder	17.8	16.4	29.9	138.4	102.3
TOTAL	1998.6	2328.9	4008.4	5358.5	4971.0

SOURCE: *Aluminum Statistical Review*

The data on ingot shipments include ingot shipped for exports, steel deoxidizing, alloying, coating, and casting. Castings account for about 61 percent of ingot shipments. A growing practice has been to ship molten ingot in ladles directly from the reduction

plants to the customer for casting. The "hot metal" is sold for about 10 percent less than regular extruded ingot to large customers, and has found a large market in automobile manufacturing.

Foreign Consumption by End Use

According to OECD data available after 1958, end-use consumption patterns in the United Kingdom, the European Economic Community (EEC), and Japan are substantially different from the United States. Transportation is by far the largest market in all three areas. In the United Kingdom the remaining consumption is divided fairly evenly among "electrical engineering," appliances, building and construction, packaging, and machinery and equipment, with no one end use accounting for a large proportion of shipments. Similar patterns can be discerned in the EEC and Japanese data. The major differences between U.S. and foreign consumption patterns are that building and construction represent a much smaller market and that aluminum consumption in appliances has a much higher growth rate in foreign countries than in the United States.

U.S. Consumption by End Use

The largest single market for aluminum in the early postwar period was building and construction, which in 1946 accounted for 29 percent of total U.S. consumption. "Other" applications, which include shipments for defense applications, accounted for 28 percent of consumption. In order of size, the remaining markets for aluminum in 1946 were consumer durables

(13 percent), transportation (9 percent), electrical applications (8 percent), and containers and packaging (3 percent). By 1952 consumption in transportation had increased to 32 percent of total consumption, while building and construction had declined to 15 percent and other applications had declined to 20 percent. Some of the changes in the percentage breakdown of consumption may have been caused by a reclassification of certain shipments from other (which included defense) to transportation.[1]

The fastest growing markets in the 1950's were containers and packaging, which increased from 4 percent in 1952 to 7 percent of the market in 1960, and building and construction, which increased from 15 percent to 30 percent. Transportation declined to 19 percent of the market, followed by electrical applications (13 percent), consumer durables (13 percent), and machinery and electrical (8 percent). The relative shares of the different markets remained essentially unchanged during the 1960's; the highest growth sectors have been electrical applications, which increased from 13 percent of the market in 1960 to 15 percent in 1970 and containers and packaging, which increased from 8 percent to 16 percent. The following were the major end uses of aluminum in 1970:

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[1] *Minerals Yearbooks* and *Aluminum Statistical Review*

End Use	Percent
Building and Construction	25
Transportation	17
Containers and Packaging	16
Electrical	15
Consumer Durables	10
Machinery and Equipment	7
Other	9

From 1960 to 1970 total shipments of aluminum products increased from 2.366 to 5.055 million short tons (See Table 3-1).

Major Aluminum Markets

Building and Construction

Since 1960, U.S. consumption of aluminum in building and construction has grown more slowly than the other major aluminum applications. As about 60 percent goes for residential construction, the housing slump of the mid-1960's may account for the low growth rate. Consumption, which was 609,000 tons in 1960, grew to only 1,125,000 tons in 1970.

No one market accounts for a significant percentage of aluminum consumption in construction. The Aluminum Association publishes data on only four end uses, accounting for about 25 percent of total consumption: residential siding (165,000 short tons in 1970), awnings and canopies (58,000), bridges and highways, (61,000 tons), and gutters and downspouts (21,000 tons).

Table 3-1

SHIPMENTS OF ALUMINUM BY MAJOR MARKET, 1960-1970

(Thousands of Short Tons)

	1960	1965	1967	1969	1970
Total Aluminum Industry Shipments	2366	4075	4473	5412.5	5055
Building and Construction	609	961	967	1187.5	1128.5
Transportation	428	898	890	993.0	766.0
Consumer Durables	257	430	416	531.0	466.5
Electrical	264	541	624	712.5	679.0
Machinery and Equipment	167	289	309	350.5	302.0
Containers and Packaging	161	328	434	597.0	733.5
Exports	309	287	329	535.0	403.0
Other	174	342	507	503.5	580.5

SOURCES: *Aluminum Statistical Review; Metals Week.*

The two largest aluminum products in the category of building materials are residential siding (14 percent of shipments) and "primary doors and windows" (10 percent). Aluminum siding was introduced in the early 1950's, and now has about 50 percent of the siding market; its principal substitute is steel. Well over 50 percent of new residential construction units have aluminum windows, whose market share has been increasing at the expense of wood and steel.

Aluminum competes with a wide variety of other materials in building and construction, including steel, wood, copper (for plumbing, tubing, roofing, and gutters), and plastics. The principal plastic product competing with aluminum is PVC (polyvinyl chloride), which is finding a growing market in siding, pipe, windows, trim, and gutters. PVC is light, easily formed, and can be produced in different colors and finishes. In addition, PVC is available at substantially lower prices than aluminum, both in terms of volume and of weight.

The Aluminum Association data on aluminum consumption in building and construction include consumption in mobile homes, an application that is different in nature than the other construction applications. Consumption of aluminum in mobile homes grew rapidly from about 40,000 tons in 1960 to 136,000 tons in 1967.[1] Production of mobile homes has grown more rapidly throughout the postwar period than traditional home construction. The typical mobile home contains an average of 350 pounds of aluminum in siding, windows,

[1] *Metals Week*, October 14, 1968, p. 15.

and doors. Aluminum manufacturers are trying to encourage sales of aluminum roofing to this industry, but mobile home manufacturers prefer steel for roofing, saying that the cost of aluminum for this purpose is too high.

Transportation

Transportation consumed 993,000 tons of aluminum in 1969 in the United States, representing about 20 percent of total U.S. aluminum consumption. In 1970 consumption declined sharply to 766,000 tons. About 40 percent of these shipments were consumed by the automotive industry; aircraft consumed 25 percent and trailers, commercial vehicles, and railways took the remainder. Railway, rapid transit and marine applications account for less than 4 percent of aluminum usage in transportation, and therefore are not considered below. The transportation industry consumes aluminum in four basic shapes: ingot (47 percent of total shipments); sheet (25 percent); extrusions (15 percent), and plate (7 percent). Wire and foil products account for the remaining shipments.

Automobiles

Passenger cars are the largest single application for aluminum in the transportation sector. The quantity of aluminum contained in the average car grew from 25 pounds in 1954 to 72 pounds by 1968.[1] Over 8.8 million cars were produced in 1968, so total alum-

[1] *Automobile Facts and Figures*, Automobile Manufacturers Association, 1968.

inum consumption in new passenger cars in that year was about 319,000 tons.

In the automotive market aluminum competes with copper (radiators and wiring), iron and steel (engine blocks), zinc die castings (decoration), and plastic (decoration).

The average aluminum content of different automobile components was as follows in 1967:[2]

Aluminum Automobile Components, 1967
(Average Pounds per Car)

Transmission	25.8
Engine	21.6
Hardware and trim	9.3
Electrical	4.3
Air conditioning	4.0
Body	2.4
Brakes	2.1
Steering	1.3
Metallic paint	0.2
Total	71.0

Despite the major advance represented by the Vega's aluminum engine block, aluminum usage per car declined in 1970, because of the higher proportion of four and six cylinder cars being produced, which use smaller aluminum power train parts and fewer aluminum accessories.

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[1] *American Metal Markets*, 1967 Aluminum Supplement, Section II, November 27, 1967.

The two most important potential markets for aluminum in automobiles are in the engine block and the radiator. The Vega has proven the commercial possibilities of aluminum engine blocks, but there is no sign that other cars will switch to aluminum over the next 3-5 years.

A number of manufacturers are considering replacing copper radiators with aluminum radiators, which would increase aluminum sales by as much as 80 million pounds per year (assuming 8 pounds per radiator). An aluminum radiator would weigh about half as much as a copper radiator, which averages about 16 pounds, and would cost about 20 percent less to manufacture. However, auto industry officials cite inexperience and the cost of converting radiator fabricating facilities as barriers to the widespread displacement of copper radiators.[1] On the plus side, a new process which replaces copper fins with aluminum and fuses them to brass tubing is being tested by several trucking firms.[2]

Other potential applications for aluminum in automobiles are hub caps and bumpers, steering wheels, brakes, new structural extrusions and paneling for trucks, and possibly driveshafts, althogh large-scale consumption in these applications is not imminent.

Aircraft

In general, about 80 percent of an aircraft's weight is aluminum. The three major competing materials for aerospace applications are steel, aluminum,

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[1] *Metals Week*, January 18, 1971.

[2] *Metals Week*, June 21, 1971.

and titanium. Titanium was chosen for the SST for air-frame, engine, and skin to meet high-speed, high-temperature requirements. Titanium has been proposed as a substitute for aluminum in a number of planned aircraft programs, because of its greater strength and higher heat resistance. New aerospace alloys are being developed to improve aluminum in these areas. There is little likelihood, however, that aluminum will be replaced in the foreseeable future as the major aircraft material (under reasonable assumptions about relative prices).

Commercial Vehicles

The subcategory of trailers and semi-trailers also includes van-type freight containers. Altogether, shipments to this group are 7 to 8 percent of total transportation shipments.

According to one 1963 estimate, two-thirds of all tank trucks and van trailers used aluminum bodies.[1] An average urban bus, according to the same source, uses 3.1 tons of aluminum. One manufacturer estimated bus production in 1961 at 1,500 units, which would mean shipments of 4,650 tons of aluminum to the bus industry in that year alone.[2]

Containerization is a new field in which aluminum and steel compete. Aluminum manufacturers say that presently 80 to 85 percent of all containers have aluminum framework, side panels, and roofs. Steam-

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[1] *Chemical Week*, September 15, 1962.

[2] *Ibid.*

ship operators are presently the largest users of containers; but the trucking industry will probably become the largest market. As in the case of aircraft, there is little likelihood that aluminum will be replaced by other metals in this market.

Electrical and Communications Equipment

The electrical and communications market is one of the fastest-growing applications for aluminum. The major fabricated shapes shipped to this market are ACSR (aluminum cable, steel reinforced) and bare cable, which together represent shipments of 466,000 tons (or about one-third of the total). Another 17 percent of the shipments are insulated or covered wire and cable.

Aluminum has been rapidly displacing copper in many electrical applications, partly as a result of the high and rising price of copper during the past decade. Aluminum's principal advantages in this market are its ductility, lightness, high strength-to-weight ratio, and conductivity (aluminum is twice as conductive per pound as copper). Aluminum's principal disadvantage is that it corrodes in closed, moist environments. Between 1958 and 1970, U. S. shipments of aluminum wire products increased from 135,000 tons to 427,000 tons.

The major use for aluminum in the electrical market is in power and transmission distribution. This use takes two-thirds of the aluminum shipped to the electrical market. It is estimated that 90 percent of overhead distribution systems are aluminum; towers

and supporting structures are also of aluminum[1] Recently, high-strength aluminum alloys have been used instead of steel as the cable's reinforcing core. Because of aluminum's susceptibility to corrosion, aluminum urban residential distribution (URD) systems cannot be exposed to the weather; for these applications aluminum cables are insulated with high-density polyethylene.

Other electrical uses of aluminum are in electronics and communications equipment and parts; rigid conduit and electrical metallic tubing; and lighting fixtures and electric lamps.

A rapidly growing market for aluminum in recent years has been wire for home electrical conductors. Between 1964 and 1967 aluminum consumption in electrical wire grew from 5,000 to 21,000 short tons, while copper consumption in electrical wire declined from 225,000 to 220,000 tons.

A number of possibilities exist for further displacement of copper by aluminum in electrical and communications equipment, particularly in insulated overhead wire, and telephone cable. A boost to further inroads may come from a new nickel-coated aluminum wire which improves upon the existing copper-coated wire with respect to lightness and protection against failure at joints and connection.

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[1] *Metals Week*, October 14, 1968.

Containers and Packaging

Containers and packaging was the largest-growing single market for aluminum during the 1960's. About 60 percent of the aluminum shipped to this market is in the form of sheet and foil.

The major packaging products are all-aluminum beverage cans, composite cans, flexible packaging products, semi-rigid foil containers, and consumer foil. As aluminum is nontoxic, it is easily adaptable for containing food and beverages. Its good thermal conductivity allows the product to be heated or chilled easily. The fastest growing application is in metal and composite cans, which grew steadily from 23,500 short tons in 1960 to 456,500 short tons in 1970. During the same period, shipments of aluminum foil grew from 112,000 tons to 239,500 tons and shipments for other container applications grew from 25,000 tons to 37,500 tons.[1]

Several commercial developments occurred in this market during the 1960's. Composite foil-fiber cans, developed in 1962 had captured 91 percent of the frozen juice can market and 80 percent of motor oil can market by 1965. Aluminum foil-lined, six-ounce cans cost $19.50 per thousand, compared with $21.50 for tin-plate. Even further cost savings are possible with a new plastic-lined composite can, introduced in 1966. The new composite can costs 4 percent less than the typical foil-fiber can and may replace it in the frozen juice and motor oil can markets. However, this product will probably not soon displace metal cans in the beverage container field as pressure pack-

[1]Aluminum Association, 1970.

aging for beer and other beverages requires thicker and stronger materials than the present composite can.

The beverage can market underwent rapid evolution in the 1960's. In 1960 cans with tabs for easy opening were developed and the tear-top lid was introduced in 1964. As the design of these cans relied on aluminum such developments had revolutionary implications for aluminum consumption in beverage containers. Aluminum consumption in this application began to increase in 1963 and increased sharply in 1964 when two large breweries began marketing beer in an aluminum can. Consumption in succeeding years has grown rapidly, and by 1968 it was estimated that aluminum held about 7 percent of the total beverage can market and well over 75 percent of the market for can ends.

The most serious competitors to aluminum are tinplate, plastics, and tin-free steel. The importance of tinplate appears to be declining, but the other two substitutes may be very important in the future. Low-density polyethylene plastic is used for food containers, film, bottle tops, and wrapping paper. Rigid plastic containers and bottles of PVC are being developed in an effort to penetrate the metal can market. Tin-free steel was developed in the beverage containers market in 1965 and may regain some of the markets lost by tinplate in the 1960's A number of firms are currently experimenting with both aluminum and steel cans.

Consumer Durables

In the 1920's and 1930's consumer durables was the single most important market for aluminum, but

by 1970 this application accounted for only about 10 percent of total shipments. Aluminum shipments to this market (primarily in the form of sheet and castings) grew by an average of 8 percent between 1960 and 1969 but declined sharply in 1970. The largest single application in this market is refrigeration including home and commercial air conditioning, which accounts for more than 25 percent of total shipments.[1] Cooking utensils account for about 14 percent of total shipments, followed by pleasure boats and outboard motors (11 percent), furniture, major appliances other than refrigerators and air conditioners, portable appliances (such as ice crushers, meat grinders, hair dryers and can openers), sporting and athletic goods, and luggage. According to industry sources, consumption of aluminum in air conditioning equipment may increase substantially in the future.

The principal substitutes for aluminum in this application are copper (for refrigeration and cooking utensils), steel (for furniture and cooking utensils), fiber glass reinforced plastic (for pleasure boats), and magnesium (furniture and sporting goods).

Machinery and Equipment

The largest applications in this market are in special industry machinery, agricultural machinery, and materials handling equipment, followed by irrigation equipment, process industries, service equip-

[1] *Metals Week, Aluminum: Profile of an Industry*, 1969, p. 91.

ment and supplies (barber and beauty shop equipment, ladders, office machines and scales), components (fasteners, hardware, and identification equipment), and other machinery and equipment (including compressors, engines and turbines, and fire-fighting equipment).

Consumption in machinery and equipment has grown fairly steadily, averaging 12 percent annually from 1960 to 1969. Three new applications may lead to substantial growth in the next decade: desalination, cryogenics, and oil and gas drilling pipe.

Copper-nickel, aluminum, titanium, stainless steel, and plastics are all being examined for use in desalination, although copper-nickel appears to be the most likely material to be used. The total potential market for aluminum in this application is 120,000 tons, about one-third of total consumption in machinery and equipment in 1969. Copper-nickel may obtain most of this market because of its long life expectancy and good corrosion resistance, but Alcoa and Reynolds have established pilot plants in the hope that they can show that aluminum's low cost can offset these disadvantages.

Cryogenic applications for aluminum include the storage of liquified gases in tanks at extremely low temperatures. Aluminum has good strength and tensile properties at low temperatures and alloys 5083 and 7039 are already used in 50 percent of the inner tanks of cryogenic vessels.

Defense

Only incomplete data exist on shipments for defense.

Direct shipments to defense are classified by the Aluminum Association as "other applications," which accounted for 546,000 tons in 1969 (or about 11 percent of total shipments). Indirect military shipments are dispersed in the Aluminum Association data among transportation, construction, and other major aluminum markets.

According to Bureau of Census data, direct military shipments declined from 397,000 short tons in 1952 to 128,000 tons in 1954 and remained at low rates during the following decades, falling to a low of 72,000 tons in 1960. Beginning about 1965 direct military shipments began to increase rapidly, increasing from 100,000 tons in 1964 to 409,000 tons in 1966 and 444,000 tons by 1967. By 1970, however, shipments had fallen to 206,000 short tons. During this period the percentage of total aluminum shipments accounted for by direct defence shipments increased from 3 percent to 6 percent. These data suggest that most of the shipments classified as "other applications" by the Aluminum Association are direct defense shipments.

It was estimated in 1968 that total direct and indirect shipments for defense accounted for about 12 percent of total aluminum shipments.[1] As direct shipments in that year were about 10 percent of total shipments, this indicates that only about 2 percent of total shipments are indirect military shipments.

The major applications for aluminum in the Vietnam War include atomized powder for explosives, small aircraft and helicopters, portable equipment. military vehicles, missiles, electronic equipment, and ships.

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[1] *Metals Week.*

Aluminum defense shipments can be expected to depend to some extent on the scale of the U.S. involvement in the Vietnam War, although shipments will probably remain fairly substantial even when U.S. forces are completely withdrawn from Vietnam.

Other Applications

The remainder of shipments in the "other" category are equal to about 50,000 tons (or about 1-2 percent of total shipments). These shipments are used in such applications as abrasives, chemicals, ceramics, glass products, and refractories. The manufacture of mining explosives consumes about 18,000 tons. Additional minor applications include removal of impurities in steel manufacturing and the use of aluminum as a fuel additive and as an ingredient in cement production. Aluminum paste is used largely for protective paint coatings; the remainder is used for industrial finishes. Aluminum flake is used in industrial explosives, printing inks, coldbody solders, and vinyl fabric coatings.

Substitution and Outlook for Aluminum Consumption

Charles River Associates has conducted extensive econometric investigations of the demand for aluminum. These studies have shown high and significant elasticities of demand for aluminum with respect to deflated aluminum prices in all end uses except containers and packaging and defense.

Significant substitution effects have been found with copper in construction and electrical applications. No statistically significant substitution effects have been found with other metals.

The estimated elasticities in each end use with respect to aluminum prices, copper prices, and "activity" variables are presented in Table 3-2.[1]

The term elasticity is defined as the percentage change in consumption divided by the percentage change in the variable in question. Thus, if a 10 percent increase in price causes a 10 percent increase in consumption, the estimated elasticity will be equal to -1.0. The short-run elasticities above are measured for one year; i.e., they indicate the effect on consumption in one year of a change in price. The long-run elasticities measure the effects on consumption over a period of several years.

According to our econometric analysis, the long-run elasticity of aluminum consumption with respect to the deflated aluminum price is -1.646. Thus, if there is no change in copper prices, a 10 percent increase in the aluminum price relative to the general price level in the economy will cause about a 16 percent decline in aluminum consumption. The corresponding short-run (one-year) elasticity is -0.31. The long-run elasticity with respect to copper prices is estimated to be about .357, indicating that a 10 percent increase in copper prices, other things

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[1]Activity variables measure manufacturing activity in user industries for each application.

Table 3-2

ELASTICITIES WITH RESPECT TO:[1]

	% of 1970 Consumption	Transaction Price of Aluminum Short Run (One-Year)	Transaction Price of Aluminum Long Run	Copper Price Short Run (One-Year)	Copper Price Long Run	Activity Variables
Transportation	20.2	-1.04	-41.8	-	-	1.10
Construction	24.2	-0.25	-1.52	+0.05	0.29	1.10
Electrical	14.5	-0.17	-1.98	+0.17	+1.98	1.48
Consumer Durables	10.8	-0.11	-0.66	-	-	1.10
Machinery and Equipment	7.1	-0.09	-1.12	-	-	1.31
Containers and Packaging	12.2	-	-	-	-	-
Other	10.9	-	-	-	-	-
Weighted Average		-0.31	-1.646	+0.037	0.357	

[1]All elasticities are calculated at the means of the variables. Equations were actually estimated using the price of scrap clippings as a proxy for aluminum transaction prices. To convert the estimated elasticities with respect to the scrap price to elasticities with respect to primary ingot prices, it was assumed that ingot prices are on the average about double the level of scrap prices.

remaining equal, will cause aluminum consumption to increase by about 3.5 percent.

With the exception of containers and packaging, the estimated activity elasticities range between 1.10 and 1.48, indicating that aluminum consumption, other things remaining equal, grows somewhat faster than the general economic activity. The analysis of the end-use markets indicates that within current price ranges there is little prospect that aluminum will either gain or lose any major markets in the next three to five years. The econometric results indicate that in the absence of changes in aluminum and copper prices, aluminum consumption over the next few years should grow at a rate about 25 percent greater than the growth in the economy as a whole.

Chapter 4

STRUCTURE OF THE ALUMINUM INDUSTRY

From its "birth" in 1886 through the first half of the 20th Century the aluminum industry was dominated by two integrated firms: The Aluminum Company of America in the Western Hemisphere and Péchiney in Europe. During the postwar period the industry has become less concentrated and by 1969 about 77 percent of the industry's output was split among six integrated firms and the remainder was divided among several dozen smaller concerns, many of which are not integrated.

The high concentration of the aluminum market can be attributed to a number of entry barriers, which have become less important over time:

1. Until the 1940's the processes for the manufacture of alumina and aluminum were protected by patents and in some cases were trade secrets.

2. The minimal efficient scale for an integrated producer is at least 165,000 tons, or more than one-fourth of the total noncommunist market in 1939. The importance of this barrier to entry has declined over

time with the growth of the market, and by the late 1960's the minimal efficient scale represented less than 3 percent of the market.

3. A minimal estimate of the capital cost of an integrated operation is $149-263 million, and this cost may run as high as $1 billion.

4. The technology of aluminum production is complex and there are a number of proprietary processes used by the established firms. It seems reasonable that entry would be restricted to those firms with some familiarity with aluminum technology.

5. It is logistically difficult to initiate bauxite, alumina, and aluminum production simultaneously.

6. Possession of a high-quality bauxite deposit is perhaps the most important barrier to entry in aluminum production. No firm has been able to grow to an appreciable size without obtaining its own bauxite supply.

Current Structure of the Industry

The present organization of the aluminum industry reflects a long process of evolution from small, localized monopolies to a complex, international industry in which the principal firms are linked by corporate affiliation and by transactional ties. The majority of manufacturers who are not subsidiaries of the large international companies are either state owned or at least partially controlled by national governments.

Table 4-1 lists the date of entry, the state of integration, and aluminum production capacity as of the end

Table 4-1

MAJOR ALUMINUM COMPANIES IN THE NONCOMMUNIST WORLD

Name	Country	Date of Entry	Ownership by Other Aluminum Companies	State of Integration	Ingot Capacity at End of 1969 (short tons per year)
Péchiney[1]	France	1888	--	Full	318,478
Aluminum Company of America	U.S.	1888	--	Full	1,325,000
Swiss Aluminum Limited	Switzerland	1888	--	Full	71,630
British Aluminum Company Limited	U.K.	1896	--	Full	42,978
Alcan Aluminum Limited	Canada	1900 1950	Owned by Alcoa until 1950	Full	1,000,000
VAW[2]	Germany	1918	--	Full	220,400
Montecatini Edison	Italy	1928	--	Full	92,568
Showa Denko[3]	Japan	1934	--	Alumina fwd	185,467
Nippon Light Metals Co., Inc.	Japan	1940	50% Alcan, 1953	Alumina fwd	214,780
Reynolds Metals Co.	U.S.	1941	--	Full	935,000
Kaiser Aluminum and Chemical Corp.	U.S.	1940	--	Full	710,000

Footnotes on following page

Table 4-1

MAJOR ALUMINUM COMPANIES IN
THE NONCOMMUNIST WORLD (Continued)

Name	Country	Date of Entry	Ownership by Other Aluminum Companies	Integration	Ingot Capacity at End of 1969 (short tons per year
A/S Aardal og Sunndal Verk	Norway	1948	50% Alcan	Aluminum Only	293,131
Sumitomo Chemical Company	Japan	1944	--	Alumina fwd	171,581
Anaconda Aluminum Co.	U.S.	1955	--	Aluminum fwd	175,000
Harvey Aluminum, Inc.	U.S.	1958	--	Full	91,000
Kasei Naoetsu	Japan	1963	--	Aluminum fwd	118,465
Ugine-Kuhlmann	France	1966	--	Full	93,670
National Southwire	U.S.	1969	--	Aluminum fwd	122,000
Revere Copper and Brass	U.S.	1970	--	Alumina fwd	112,000
Alsar	Italy	1970	part Montecatini Edison	Aluminum fwd	110,200

Notes: The companies listed account for over 99 percent of noncommunist aluminum reduction capacity.

[1] Péchiney Compagnie de Produits Chimiques et Electrométallurgique
[2] Vereinigte Aluminum - Werke Actiengesellschaft
[3] Showa Electro-Chemical Industry Co., Ltd.

of 1969 for each principal independent aluminum producer in the noncommunist world. The capacity data include the capacities of the affiliates and subsidiaries of the major producers.

Until 1940 there was only one primary aluminum producer in the United States and 17 in the entire world. By 1968 eight firms produced primary aluminum in the United States and 50 companies in 25 nations operated aluminum smelters in the noncommunist world. However, the bulk of the noncommunist world aluminum industry from mining through reduction in recent years has been controlled by *six* integrated producers of international scope: Aluminum Company of America, or Alcoa, Reynolds Metal Company, Kaiser Aluminum and Chemical Corporation (all in the United States), Alcan (Canada) Compagnie Péchiney (France), and Schweizerische Aluminium A.G., or Alusuisse (Switzerland).

Since the establishment of the industry in 1888, it has been principally in the hands of a few large organizations, three of which trace directly to the original producers.

The entry of Kaiser, Reynolds, and Alcan in the early postwar period in effect converted the world aluminum industry from a three-firm market to a six-firm market. It is notable that the entry of all three new firms was directly caused by U.S. government policy--by subsidy in the case of Kaiser and Reynolds and by court action in the case of Alcan, which was split from Alcoa by court action.

Although a number of other producers have initiated aluminum production in the postwar period, the concen-

tration of ownership of aluminum production facilities has showed little decline since 1953. In that year the top six firms accounted for 87 percent of noncommunist aluminum capacity. Primarily as a result of the entry subsidized by the U.S. government, the market share of the "Big Six" declined gradually to 79.2 percent by 1958. The share increased to 83 percent in 1959, largely as a result of Reynolds' acquisition of British Aluminium, and has since declined very slowly to 77.0 percent. The world market shares in 1969 were as follows:

Alcan	19.2 percent
Alcoa	19.0 percent
Reynolds	13.3 percent
Kaiser	10.9 percent
Péchiney	9.1 percent
Alusuisse	5.0 percent

The major aluminum ingot producers are all integrated from bauxite mining through ingot production and in most cases through production of semifabricated products as well. It is therefore not surprising that ownership data reveal very high market concentration in bauxite and alumina production as well as in aluminum ingot production.

For example, if the known capacity of each bauxite mine is attributed to the firm with majority control of the mine, and if the capacities of joint ventures are attributed to parent firms in proportion to equity holdings, the known holdings of the top seven firms amount to 78 percent of total reported noncommunist bauxite capacity:

Kaiser	19.7 percent
Alcoa	16.6 percent

Reynolds	15.1 percent
Alcan	14.0 percent
Billiton	5.4 percent
Péchiney	5.1 percent
Alusuisse	1.8 percent

The share of the six traditional majors (Kaiser, Alcoa, Reynolds, Alcan, Péchiney, and Alusuisse) is 74.3 percent. It should be emphasized that much of the residual mining capacity may be indirectly controlled by the major integrated firms (through interests in participating companies, long-term purchase contracts, etc.).

Ownership of alumina facilities is even more concentrated than that of bauxite mines. As of 1968 the six traditional majors controlled about 84.2 percent of noncommunist world alumina capacity:

Alcoa	24.1
Alcan	20.5
Kaiser	14.9
Reynolds	12.8
Péchiney	9.2
Alusuisse	2.7

The aluminum industry can still be regarded as extremely concentrated at each of the three principal stages of production. Six vertically integrated firms firms account for almost four-fifths of noncommunist aluminum capacity. If the capacities of several additional firms (such as Ormet and Harvey) are included, this figure approaches five-sixths of total aluminum capacity. In addition government-owned firms in protected markets account for about 4 to 5 percent of total capacity. If the capacities of these firms are excluded from the total,

the aluminum capacities of the top seven or eight firms in the industry are about 90 percent of total noncommunist capacity serving international markets. Alumina production is even more concentrated than aluminum production.

Secondary aluminum, however, is a substitute at the margin for primary aluminum, and as the secondary aluminum market is competitive the effective market shares of the major integrated firms are smaller than are indicated by examining only primary capacity. If secondary production capacity is included in the capacity calculations the 1962 share of the top six firms of total capacity declines from 79.9 percent to 71.3 percent. However, the degree of concentration in the secondary industry is less important for market behavior than the degree of concentration in the primary industry.[1]

Current Trends in Industry Concentration

Fourteen new firms have announced their intention to construct aluminum capacity in the next five years. Three of these are affiliates of established firms -- Anglesey Aluminum Works, Alusaf, and Gulf Coast Aluminum. The remainder are essentially new entrants into aluminum production, although the established firms have minority holdings in many of these firms. A survey of the available information shows that many of the new concerns are either small nonintegrated smelters or are government-

[1]Secondary producers cannot really be regarded as a competitive fringe because their output will always be a fairly stable proportion of primary production.

controlled enterprises established to serve protected local markets.[1]

The most important new entrant is American Metal Climax (AMAX), which has recently acquired huge commercial bauxite reserves in Australia. To develop these reserves, AMAX has set up a consortium with Sumitomo Chemical, Showa Denko, Holland Aluminum, and VAW to complete a bauxite-alumina complex in 1973 or 1974. AMAX Bauxite Corporation has been established with plans to construct a 600,000-ton alumina facility by 1973.

AMAX also recently purchased the properties of Northwest Aluminum, a joint project of Bell Intercontinental and three Japanese firms. Northwest planned to construct a smelter in Oregon, taking advantage of a subsidized power contract. AMAX is said to be considering building a 150,000 tpy smelter on the properties to refine alumina from its Australian operation and is reportedly also studying other smelter sites both in and out of the United States.

The projected entry by AMAX into the aluminum industry is very significant, for it will be the only firm in the postwar period to enter the aluminum industry on a large-scale integrated basis without special government incentives. The firms that have attempted to enter the industry and have failed to obtain even a moderate share of the market include many firms with ample capital reserves, expertise in nonferrous metals technology, and incentives to obtain a strong position in the aluminum market (Anaconda, Revere Copper and Brass, Copper Range,

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[1]See our March 1971 report to GSA, pp. 3-59 to 3-63.

Noranda Mines, and National Steel). In fact, AMAX has been attempting to gain a foothold in the aluminum industry for a number of years and is a partner in Intalco, a nonintegrated firm formed as a joint venture of AMAX, Howmett, and Péchiney. It appears that AMAX now has the one asset that the other firms lack -- a rich bauxite deposit.

The other major new entrant is part of a $400 million Greek industrial complex. The current plans call for completion by 1973 of a 500,000-ton alumina plant and a 120,000-ton aluminum smelter. The bauxite source for this project has not been announced, although limited commercial deposits of bauxite exist in Greece. It is difficult to determine how seriously this project should be regarded, but if it is successfully completed it will have about 2 percent of noncommunist alumina capacity and about 1 to 2 percent of noncommunist aluminum capacity.

Several other new firms plan to enter on a modest scale but may bear watching over time. In particular Noranda Mines Limited, a large copper producer, planned to complete a 75,000-ton smelter in Missouri in 1971.

If all of the planned capacity construction by new firms occurs on schedule and if no major new projects are initiated by the established producers, the market share of the six principal integrated firms would decline from 76.6 percent in 1970 to 61.9 percent in 1971.[1] The actual decline in industry concentration will, of course, be much less than this.

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[1]See our March 1971 report, pp. 3-67 to 3-70.

Chapter 5

PRICES IN THE ALUMINUM INDUSTRY

Elemental aluminum is sold in a large number of forms, including bauxite, alumina, alloyed and unalloyed primary aluminum ingot, secondary alloyed ingot, hot metal, and an almost infinite number of semifabricated and fabricated products. Very little aluminum is sold in the form of bauxite and alumina. Somewhat less than one-tenth of U.S. sales of primary aluminum are in the form of hot metal, primarily to the automobile industry, about one-third of U.S. sales are in the form of primary ingot, and the balance is in the form of fabricated and semifabricated products.

The key prices for analyzing the aluminum market are the prices of hot metal, primary and secondary ingot, and semifabricated products. This chapter will focus on aluminum ingot prices, as they are the only prices for which consistent time series data exist. The available information on prices of aluminum in other forms will also be discussed.

Prices of Aluminum Ingot

The base price of aluminum is generally the price of pig or ingot. The price includes delivery to the buyer's plant, so there is no geographical differential. Pig was first introduced in 1942 as an unrefined product whose composition varied. However, with improvements in technology, the quality of pig was raised until there was little difference between pig and refined ingot. Consequently, as of August 2, 1960, the term "pig" was dropped and ingot was sold at the pig price. It appears that the standard form in which aluminum was traded until 1960 was pig, and it was the pig price that was emphasized at times of price changes. To provide a consistent price series, however, we use the list price of 99.5 percent purity ingot, which almost always changed simultaneously with the price of pig.

The list price of primary aluminum is changed on the average about twice a year. The general pattern in the postwar period has been for one firm to initiate a change in the list price of primary ingot and for the other primary producers to follow within several days. From 1947 to 1970 Alcoa was the price leader 11 times, Alcan 6 times, Kaiser 6 times, Reynolds once, and Ormet twice.

Frequently the list price of primary aluminum ingot does not represent the actual transaction price. In times of shortage, such as most of the 1948 to 1956 period, the primary producers rationed aluminum. Consumers who cannot purchase all their desired aluminum

from the primary producers must then turn either to gray markets on which transaction prices are greater than list prices or to scrap and secondary aluminum ingot. During times of surplus, such as from 1958 to 1960 and from 1969 to the present, the primary producers discount aluminum. For example, during September 1971, primary aluminum ingot was reportedly being sold at prices as low as $0.22 per pound.

Unfortunately, there are no consistent time series data on actual transaction prices. However, as the scrap market is fairly competitive and as scrap aluminum can substitute for primary aluminum in some applications, we can use the prices of scrap and secondary ingot as a proxy for primary transaction prices. Since 1960 secondary ingot has been sold on a list price basis; in recent years this price has not reflected market conditions. The scrap price, however, fluctuates on a daily basis and is a good indicator of supply and demand conditions in the aluminum market.

Table 5-1 and Figure 5-1 show for 1947 to 1970 the average annual prices of primary ingot, secondary ingot, scrap clippings; an index calculated by CRA of aluminum costs of production; and the capacity-utilization ratio of the primary aluminum industry.[1]

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[1]The CRA index is essentially a factor-price index, constructed by calculating a weighted average of the costs of factors of production used in aluminum production and correcting for technological change. The cost index assumes normal capacity utilization and use of the latest equipment, and it should therefore be regarded as an index of the long-run-per-pound average cost of producing aluminum. (See our March 1971 report to GSA.)

Table 5-1
ALUMINUM PRICES IN THE POSTWAR PERIOD
(Cents per Pound)

	List Price of Aluminum Ingot[1]	Price of Secondary Ingot[1]	Price of Scrap Clippings[1]	Long Run Cost Index of Aluminum Production[1]	Capacity Utilization (Noncommunist World)[2]
1947	15.00	14.61	8.63	13.62	NA
1948	15.73	21.00	11.82	14.87	NA
1949	17.00	17.35	11.40	14.87	NA
1950	17.71	21.08	13.16	15.08	NA
1951	19.00	25.02	15.53	16.97	NA
1952	19.40	19.43	10.40	16.97	NA
1953	20.93	21.54	12.57	18.22	0.926
1954	21.78	20.01	13.12	18.43	0.947
1955	23.67	28.49	17.93	18.22	0.931
1956	26.01	28.96	16.99	18.85	0.899
1957	27.52	22.47	14.07	19.90	0.833
1958	26.89	21.62	12.97	19.06	0.748
1959	26.85	22.94	14.40	19.69	0.805
1960	27.23	24.17	13.55	20.11	0.857
1961	25.46	22.06	11.92	19.69	0.805
1962	23.88	21.10	11.05	19.90	0.834
1963	22.62	21.26	11.56	19.90	0.878
1964	23.72	22.30	12.29	20.11	0.951
1965	24.50	24.46	14.68	20.11	0.937
1966	24.50	24.99	12.76	20.95	0.963
1967	24.98	25.00	10.49	21.37	0.934
1968	25.58	25.15	10.08	22.62	0.902
1969	27.18	27.64	13.04	24.30	0.954
1970	28.72	28.70	10.94	25.49	0.944

[1] Annual average

[2] Annual production divided by end-of-year capacity

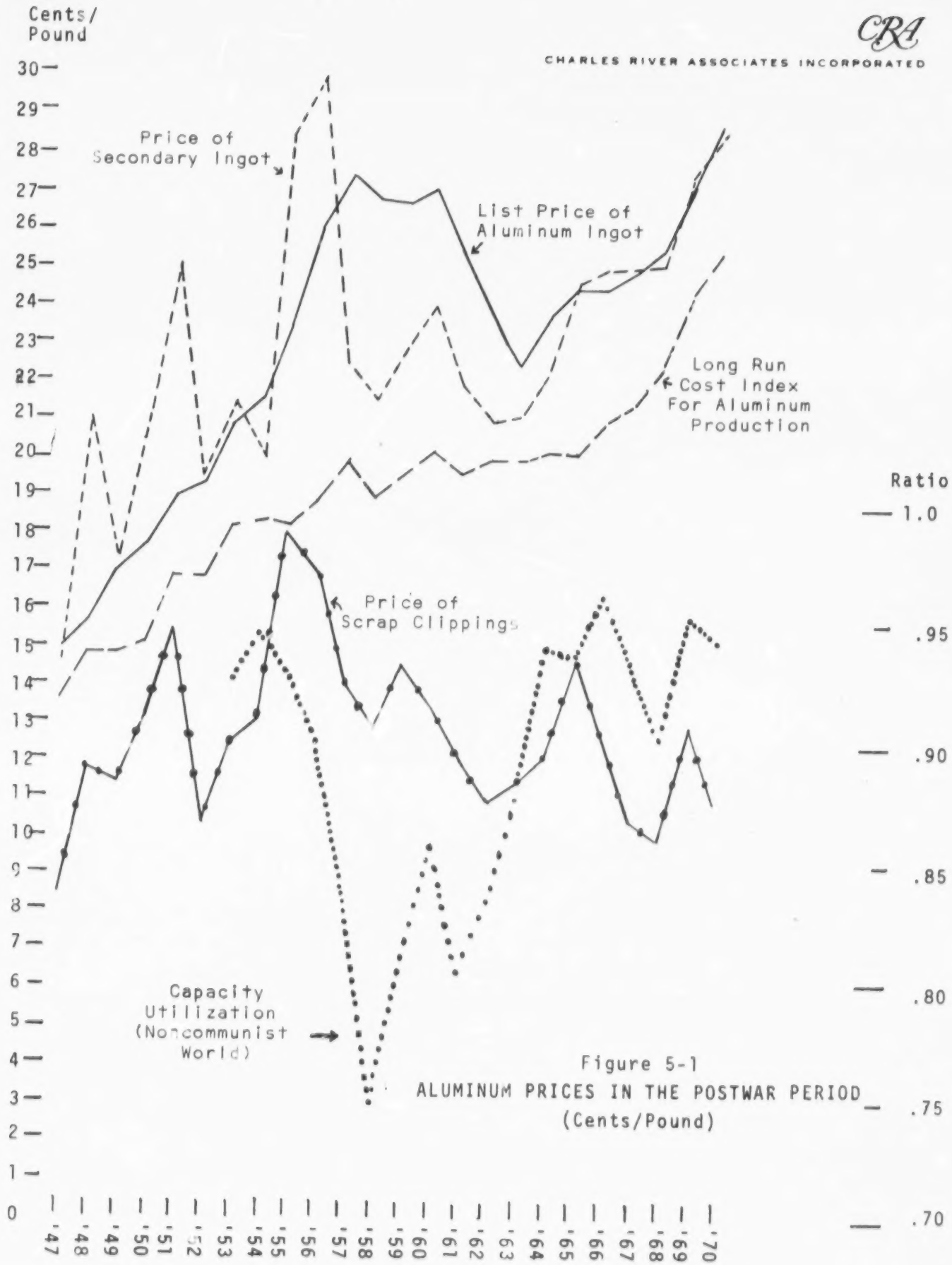

Figure 5-1
ALUMINUM PRICES IN THE POSTWAR PERIOD
(Cents/Pound)

Two distinct periods are apparent in the postwar price history: 1947 to 1958 and 1958 to the present. In the first period Alcoa initiated most price changes. The list price increased steadily from $0.15 in 1947 to a peak of $0.281 in August 1957. During much of the period demand at the list price exceeded primary supply. Rationing was therefore prevalent and in most years the prices of secondary alloyed ingot was substantially above the list price of primary ingot. In the second period (from 1958 to the present) no one firm led in changing prices. The list price fell from $0.281 per pound at the end of 1957 to $0.225 by 1963, but then increased steadily to $0.29 by 1970. There is no evidence of any significant rationing during this period.

In general, the list price of aluminum has not been highly correlated with the index of durable manufactures since the end of World War II. During the first half of the postwar period it appears that prices increased occurred in times of expansion and remained constant when the economy was declining. In the second half of the postwar period, however, there is little apparent correlation between aluminum prices and durable manufactures production. Much the same conclusions hold for the correlation between the aluminum price and U.S. production and consumption of aluminum. The list price of ingot has not been highly correlated with prices of aluminum substitutes. In particular the 1958, 1961, and 1962 reductions in the price of aluminum are not reflected in the price series for copper and steel. The price of aluminum has not increased as rapidly in

the postwar period as the prices of its principal substitute metals. From 1947 to 1969 the price of aluminum increased 56 percent, while the prices of steel and copper increased 65 percent and 62 percent, respectively. The prices of plastics, however, have declined relative to the price of aluminum, and during the last decade plastics have become increasingly important as aluminum substitutes.

The break between the two periods in the price series may reflect the declining concentration of the industry between 1947 and 1958. However, comparing the list price data with our index of production cost shows that the markup between price and cost has remained remarkably stable in the postwar period. The absolute difference between price and long-run cost has had an upward trend during the postwar period, increasing from $0.0138 in 1947 to $0.0288 in 1969. In real terms, however, there has been little discernible trend. The differential between price and cost, deflated by the wholesale durables price index, fluctuated between $0.0214 and $0.0346 during the 1947 to 1950 period, increased to levels of $0.06 to $0.08 during the 1950's, and during the 1960's has fluctuated between $0.02 and $0.04, reaching $0.0246 in 1969. The ratio of price to cost fluctuated between 1.10 and 1.17 between 1947 and 1953, increased to levels as high as 1.40 in the 1950's, and declined during the 1960's to 1.12 by 1969, virtually equal to the 1947 value of 1.10. It appears that the "normal" markup over cost is between 10 and 20 percent and that the "normal" difference between price and cost is between $0.02 and $0.04 per pound (in 1970 dollars).

As Table 5-1 and Figure 5-1 show, transaction prices of aluminum follow the list price over the long run, but often differ substantially in the short run.[1] For example, in 1948, 1951, 1955 and 1956 there was particularly tight supply in the primary ingot market, and the secondary price was substantially greater than the price of primary. From 1958 to 1963 there was aluminum surplus and discounting, and scrap and secondary prices were low in relation to the primary price. Between 1963 and 1966 capacity utilization in the aluminum market was high and there is little or no indication that discounting was practiced. Between 1966 and the present, scrap prices have declined substantially, indicating that the surplus of aluminum capacity during these years has led to substantial discounting.

As can be seen in Figure 5-1 and Table 5-1, there is generally a very good correlation between the extent of discounting in the primary market and the capacity-utilization of the primary producers. The correlation is improved if the capacity-utilization ratio of all noncommunist producers is considered, which is not surprising in view of the fact that the aluminum market is world-wide in scope.

Prices of Aluminum in Different Markets

Delivered prices of aluminum ingot and products apparently do not vary greatly within the borders of

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[1]Secondary ingot and scrap prices are used as proxies for the transaction price.

the United States. The list price of primary aluminum ingot includes delivery to the buyer's plant and there is no indication from trade journals or industry sources of significant geographical disparities in secondary prices or fabricated product prices. Continuous time series data for prices in foreign countries of secondary ingot or fabricated products have not been published.

In general, U.S. and foreign aluminum ingot prices have closely followed each other. Of course, if the difference between domestic and foreign prices were to exceed an amount sufficient to cover transportation costs and tariffs, it would be worthwhile to import ingot rather than to buy it locally. Transportation and tariff costs for importing aluminum ingot into the U.S. have been approximately $0.02-0.03 per pound since the late 1950's.

In fact, there have been only two occasions when the difference between the U.S. and foreign prices was greater than $0.02 per pound. The first was in 1951 when the United Kingdom price was $0.155 per pound and the U.S. price was $0.19 per pound. In 1951, however, transportation costs were double those of the 1957-1967 period, and the price differential was apparently not large enough to induce the U.S. consumers to import aluminum from the United Kingdom.[1] In addition, it is not clear that the 1951 U.K. price represented a free market price; it may not have been possible in fact for foreign consumers to buy aluminum at the published price.

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[1] *Chartering Annual*, Maritime Research, Inc., 1957-1967.

The second instance occurred from 1958 to 1961, when the U.S. list price was consistently above list prices in other countries and at times was as much as $0.0275 above prices in the United Kingdom, Germany, and Canada. Although the difference in list prices was almost $0.01 more than transportation and tariff costs, imports actually declined during this period. However, the U.S. list price during this period was artificially high and actual transaction prices were in effect being reduced by such practices as providing easier credit terms and more liberal freight allowances.

Prices of Fabricated Products

An examination of the available time series data on fabricated product prices suggests that prices in these markets follow the general movements in the price of ingot. Peck found that the 1947-1958 prices of most products generally fell into two categories - the rigid product prices, which closely follow ingot changes, and the flexible product prices, which changed frequently and did not appear to be closely associated with changes in the ingot price.[1] Sheet and plate, foil and rod, bar, and wire were included in the rigid product price category, while castings, extrusions, and forgings were included in the flexible product price category.

The primary factor accounting for differences in price behavior was the structure of the market producing the item. Products exhibiting rigid price behavior

[1]Merton J. Peck, *Competition in the Aluminum Industry* (Cambridge, Mass.: Harvard University Press, 1961), p. 67.

were characterized by the dominance of a few integrated producers. Flexible prices, on the other hand, generally resulted from a very competitive market situation. As of 1954, the integrated producers accounted for 94 percent of the sheet and plate shipments and about 69 percent of the foil shipments. The concentration was significantly less in flexible price products where the integrated companies only accounted for about 9 percent of the castings shipments and 47 percent of the extrusion shipments.[1]

The *transaction* prices in the rigid product price markets have fluctuated more frequently than list prices and the transaction prices can depart substantially from list prices for protracted periods of time. For example, Bureau of Labor Statistics (BLS) indexes of the list prices of aluminum wire and cable and sheet and rod have been compared with indexes compiled by the National Bureau of Economic Research (NBER) of actual transaction prices in these markets and with an index of the price of scrap aluminum. The comparisons show that the NBER series follow the scrap price series, which is a good proxy for a transaction price series for aluminum ingot, much more closely than the BLS series. This suggests that the differences between the rigid product prices and the flexible product prices are less extreme than they appear and that both types of prices tend to follow ingot transaction prices fairly closely.

At any rate, even the superficial differences between the two types of price series are less apparent

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[1] *Ibid.*

in recent years. Figure 5-2 compares the available price series on foil, extrusion .108, extrusion 3.476, rod, sheet, and primary ingot (the fabricated price series represent list prices). While the list prices of fabricated products do tend to follow changes in the price of ingot, only sheet exhibits a truly rigid behavior. Foil and rod, previously considered rigid price products, diverge from the expected pattern, although these are areas in which the primary producers account for a large percentage of the shipments.

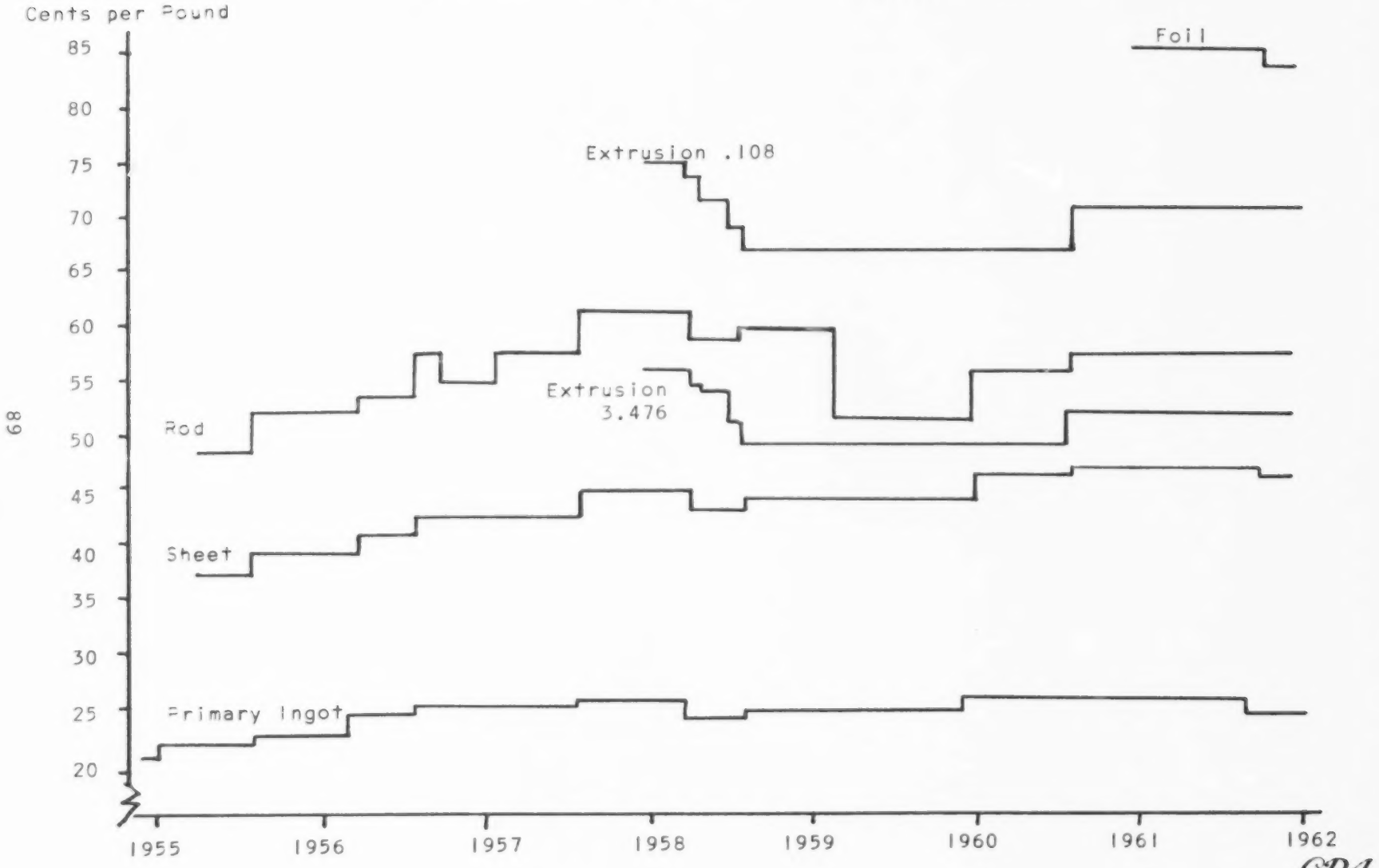
As of September 27, 1971, the list prices of selected aluminum mill products were as follows:[1]

	Dollars per Pound, Delivered
Plate, bare (.500" x 48" x 144")	
3003-F	$0.473
2024-T35	0.525
Flat sheet, bare, mill finish	
3003 (.004" x 48" x 144")	0.445
1100 (.032" x 24" x 96")	0.487 - 0.491
Coiled sheet, bare, mill finish	
3003 (.020" x 12" wide)	0.401 - 0.411
5052 (0.32" x 24" x 96")	0.430 - 0.470
Coiled sheet circles, bare, mill finish	
1100-0 (.040" x 12" diameter)	0.460 - 0.470
Plain coil foil (12-26" wide)	
.00025" thickness	$1.09 - 1.10
.00035" thickness	0.920 - 0.930
.0035" thickness	0.668 - 0.678

[1] *Metals Week*, September 27, 1971.

Figure 5-2

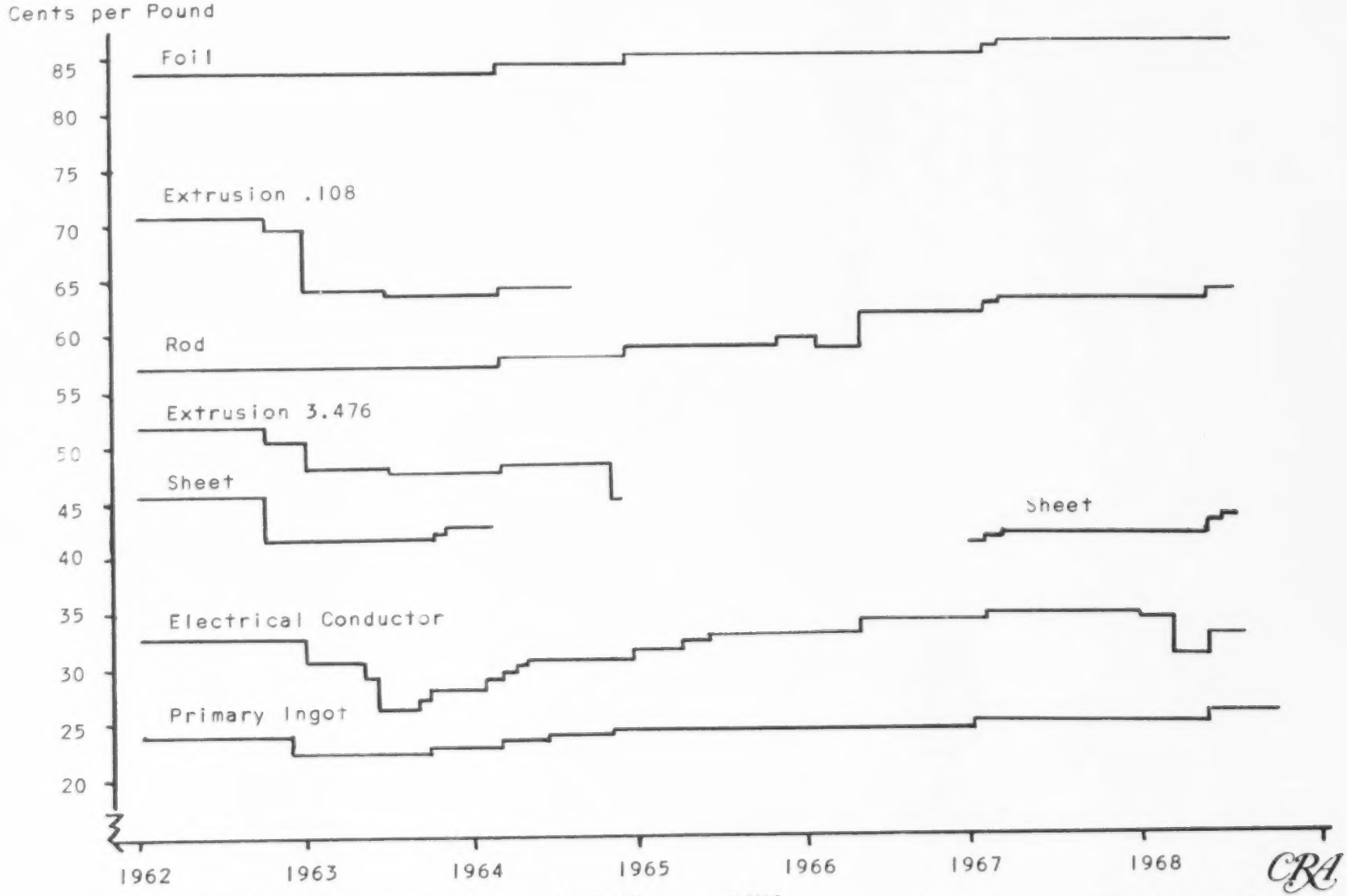
ALUMINUM FABRICATED PRODUCT PRICES, 1955-1969



CHARLES RIVER ASSOCIATES INCORPORATED

Figure 5-2 (continued)

ALUMINUM FABRICATED PRODUCT PRICES, 1955-1969



SOURCE: *BLS Wholesale Price Index;* "Ingot" from *E&MJ*

CHARLES RIVER ASSOCIATES INCORPORATED

	Dollars per Pound, Delivered
Extruded shape, factor 6-7, 2.5 lb. ft 2" circle	
6063-T5	0.460
6061-T6	0.485 - 0.495
Tube, 3" OD x .250" wall, drawn	
3003-H18	0.797 - 0.829
6061-T6	0.923 - 0.960
Wire, rod, bar, and rolled structural shapes, screw machine stock 1" diameter rod	
2017-T451	0.667
2011-T3	0.595

The actual transaction prices for most of these products are reportedly lower than the above prices.

A General Model of Price Determination in the Aluminum Market

It appears that the major integrated firms exert great efforts to support the existing list price. From 1947 to 1956 the list price of aluminum was frequently too low and demand for aluminum at that price was substantially greater than production capacity. Instead of increasing the price in these periods the producers rationed ingot, with the result that the price of secondary alloy ingot, which is a substitute at the margin for primary ingot, increased to levels substantially above the primary ingot price.

During the period from 1956 to about 1964 or 1965 and again during 1970-1971 the price of ingot was generally too high in relation to capacity, with the result that demand for ingot at this price was

substantially less than production capacity. In response to these conditions the primary producers sharply reduced production, with the result that the aggregate capacity-utilization ratio fell as low as 0.70. In addition, during periods of severe surplus capacity the primary producers offered discounts below price, partly through such means as special freight allowances. This discounting appears to have become more pronounced as excess capacity increased.

The processes generating list prices and transaction prices in the aluminum market are different. The list price is determined primarily by trends in long-run average costs and by other long-run factors, although it may be determined by short-run influences as well. The transaction price (which can be proxied by scrap prices) is determined during times of surplus by the extent to which the primary producers discount primary ingot. The degree of discounting is, in turn, determined by the extent of excess capacity in the market. In times of shortage, transaction prices are determined by competitive forces -- the price increases until the supply from secondary producers and marginal primary producers equals the excess demand of consumers being rationed by the primary producers.

As part of a system of ongoing research in natural resource markets, Charles River Associates has developed a comprehensive econometric model of the aluminum market. A simplified representation of the structure of the model can be stated in terms of three equations:

$$D_t = f_1(P_t, \bar{Y}_t); \quad (1)$$

$$PL_t = f_2(C_t, \bar{X}_t); \quad (2)$$

$$PL_t - P_t = f_3(D_t, K_t, \bar{Z}_t); \quad (3)$$

where the t subscript indicates the time period (annual) and

D = consumption,
P = transaction price (i.e., secondary ingot price),
$\bar{Y}$ = exogenous variables affecting demand for aluminum,
PL = list price of aluminum,
C = long-run average cost of production,
K = total capacity,
$\bar{X}$ = exogenous variables affecting list price, and
$\bar{Z}$ = exogenous variables affecting transaction price.

The complete model contains a number of demand and scrap supply equations, but equations (1) - (3) illustrate the basic structural relationships of the model.

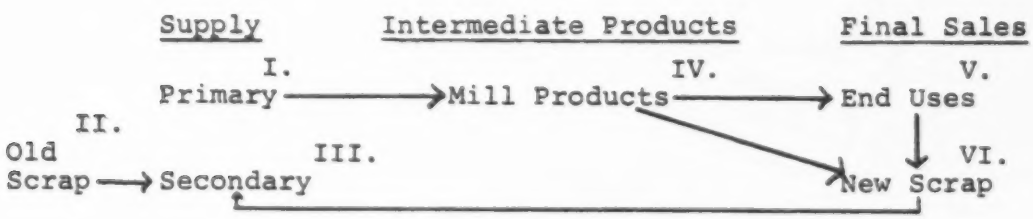
In equation (1) consumption (D) is assumed to be a function of transaction price (P) and other variables ($\bar{Y}$), such as activities affecting consumption, prices of substitutes and complements, etc. (The vector $\bar{Y}$ may also contain lagged values of P and variables in $\bar{Y}$.) It was found in the estimation that aluminum demand is very responsive to the prices of aluminum and copper. The estimated elasticities are discussed in the section on consumption of aluminum.

In equation (2), the list price (PL) is hypothesized to be a function of long-run average cost (C) and other variables ($\bar{X}$). In the estimation it was found that the list price is very highly correlated

with the CRA cost index, and that there is a distributed lag in this relationship (i.e., it takes more than one year for the list price to move to a new equilibrium). According to the best equation estimated, a 10 percent increase in costs in the long run will cause about a 10 percent increase in list price, and in the short run will cause about a 3 percent increase in list price.

Equation (3) closes the model by determining the relationship between list price (PL) and transaction price (P). This equation states that P is determined as a discount from list price by the primary producers. This discount ($PL-P$) is determined by consumption (D), capacity (K), and other variables ($\bar{Z}$). One would ordinarily expect that D and K enter the relationship as the ratio D/K (the capacity-utilization ratio). It was found that when D/K is high, the discount ($PL-P$) is small; the price discount increases as D/K declines.

The model at this point is incomplete because it does not include scrap supply. To understand the role that scrap plays in the model, it is useful to review the basic flows in the aluminum market. These flows are as follows:



Supply of ingot includes both primary ingot shipments and secondary alloy ingot shipments. Secondary alloy ingots are produced from old scrap and new scrap. New ingot supplies are made into mill products, and mill products and ingot are sold to end-use consumers. In the process of manufacturing mill products and final products, new scrap is generated and is returned to secondary ingot producers.

The ultimate consumers of aluminum are the manufacturers of final products and the consumption function in equation (1) is most appropriate if it refers to these consumers; in fact the data on shipments to consumers measure shipments to Area V. in the diagram. The consumption referred to be equation (1) is therefore defined on a gross basis, and scrap recovery must be subtracted from this consumption to obtain the net demand for new primary aluminum. The model therefore includes equations to predict scrap supply.

Chapter 6

GOVERNMENT POLICIES

At the present time the most important government policies affecting the aluminum market are those associated with the wage-price freeze, trade policies, and the stockpile disposal program. During the entire post-war period the important government policies that have had the greatest effect on the aluminum market have been those of stockpiling and of financial incentives for the expansion of production capacity. Government restrictions on the price and allocation of aluminum were far less significant during the Vietnam and Korean Wars than in World War II. Tariffs, quotas and other commercial policies have also played an important role in the aluminum industry.

Aluminum Stockpiling Program

The U.S. government began actively procuring aluminum in 1949 and heavy stockpile acquisitions were made during the 1950's. Much of the aluminum acquired

during this period was purchased in connection with a government program during the 1950's to expand aluminum productive capacity. In 1963 the federal government began disposing its surplus aluminum stocks through a program of negotiated sales with the producers.

As of August 31, 1971 the government's inventory of stockpile aluminum was 1,275,573 short tons, of which 825,373 tons were in excess of the stockpile objective and were available for disposal. In addition the government inventory of 5,694 short tons of non-stockpile grade aluminum was also available for disposal.

The excess aluminum is currently being sold under four-year contracts with the major primary producers. Each producer is committed to purchase a minimal quantity of aluminum at the prevailing list price over the four-year period, but the timing of the purchase is at the discretion of the producers. The current contract was signed in 1969 and commits the producers to purchase 385,000 tons of aluminum between 1970 and 1973. Only 6,022 tons have been sold in 1971, indicating that 379,000 tons must be sold during the next two years. At the end of this period 452,000 tons of surplus aluminum will remain in the stockpile. Most of this material will presumably be sold during the succeeding four years.

The anticipated government sales of aluminum over the next six years are large in absolute value, but it seems clear that these sales are not likely to have a substantial effect on the aluminum market. The average sales rate over this period will at most be 144,000 tons per year, or less than 3 percent of 1970 U.S. consumption and well under 2 percent of 1970 consumption in the non-communist world.

As of August 31, 1971, the government stockpile of bauxite was 8,858,881 long dry tons (LDT) of Jamaica type bauxite; 5,300,000 LDT of Surinam type bauxite, and 173,000 LDT of refractory grade bauxite. Of these totals, only 3,858,881 LDT of Jamaica type bauxite was available for sale, and this material was not being actively sold. As the cost of bauxite is only a small percentage of the cost of aluminum production, the disposal of this material would not have a substantial effect on the aluminum market, although it is possible that there might be some reduction in U.S. bauxite production as a result.

Commercial Policies and Barriers to Trade

Most countries impose low or zero tariff rates on bauxite, alumina, and aluminum ingot. A large part of international trade in aluminum is in these products. Apart from the 10 percent surcharge announced in August 1971, the duties currently imposed by the United States on aluminum products are as follows:[1]

bauxite	free
alumina	free
aluminum scrap	temporarily suspended
unwrought aluminum (ingot)	1¢/lb.
angles, shapes	11 percent *ad valorem*
unwrought aluminum in coils	1.5¢/lb.
rods, bars, plate and sheet	2¢/lb.
ingot cut to shape	11 percent *ad valorem*

[1] *Metal Statistics* (U.S., 1971) p. 45 and conversation with Mr. Peter Capeluce, U.S. Tariff Commission.

In general, U.S. duties on aluminum products are quite low in relation to the value of the products. The least processed forms have low or nonexistent duties, and the duties increase to maximum rates of 10-12 percent for more processed forms.

The economic policies instituted by the United States on August 15, 1971 obviously affect the commercial policies relating to aluminum. The 10 percent surcharge on dutiable imports became effective on August 16 and is calculated on the statutory appraised value, which is generally the invoice value, f.o.b. foreign port. The surcharge is added to the regular duty, up to the Column Two rate of the U.S. tariff schedule. (The Column Two rate is the rate applicable to countries which have not been granted preferential treatment.) The Column Two rates on aluminum products are as follows:

aluminum - unwrought in coils	7¢/lb.
aluminum - unwrought other than aluminum-silicon alloys	4¢/lb.
aluminum - wrought	7¢/lb.
bauxite - crude	$1/long ton
bauxite - calcined	$1/long ton

These rates are generally well in excess of preferential rates with the 10 percent surcharge. In general, the effect of the 10 percent surcharge is to increase the price of all imported aluminum products except bauxite and alumina by 10 percent.

The trade regulations imposed by the principal foreign consumers of aluminum are similar in pattern to

those imposed by the United States. Of course, within trade associations such as the European Economic Community, the European Free Trade Association, the Latin American Free Trade Association, and the British Commonwealth generally lower tariff rates apply than between the countries in these associations and the rest of the world.

The following are the Kennedy Round tariff levels (in percent), which were scheduled to take effect no later than January 1972:

	Canada	EEC	United Kingdom	Japan
Ingot and Billet	4.7%	9.0%	0.5%	9.0%
Sheet and Plate	2.0	12.0	8.0	18.0
Rod and Bar	5.1	12.0	8.0	12.9
Pipe and Tube	12.5	12.0	8.0	16.0
Foil-Backed	15.0	12.0	10.0	16.0
Cable	17.5	12.0	10.0	18.0
Powder	15.0	10.5	10.0	10.0

The Effects of the Wage-Price Freeze On the Aluminum Market

The wage-price freeze of August 15, 1971, set ceilings on the actual transaction prices at which aluminum products may be sold. The Treasury ruled, however, that prices could not be frozen at levels lower than those prevailing on May 25, 1970. As the transaction prices of virtually all aluminum products were substantially greater on that date than in August 1971, the price freeze has little effect on the aluminum market. The wage freeze also has little effect, as the new aluminum labor contract had already taken effect before the freeze was announced.

Chapter 7

THE ALUMINUM INDUSTRY IN THE UNITED STATES

Most of the bauxite and much of the alumina consumed in the United States is imported, while only a relatively small percentage of aluminum (less than 10 percent) is imported. Even smaller quantities of mill shapes are imported. As the value added in aluminum production is substantially greater than in bauxite and alumina production, the aluminum stage of the manufacturing process has the greatest impact on the U.S. economy.

Bauxite

In 1970, U.S. production of bauxite was 2,273,000 long tons or less than 4 percent of total noncommunist production of 54,362,000 long tons. U.S. bauxite production has shown little trend in the postwar period, remaining at annual rates slightly lower than 2 million tons during most of the period.

Arkansas produces about 95 percent of total domestic output, with the remainder being produced by Alabama and Georgia. Alcoa and Reynolds account for most of the Arkansas production. The Arkansas bauxite is mined entirely in Pulaski and Saline counties.

The known deposits of aluminum-containing ores in the United States contain about 4 billion tons of bauxite, bauxitic clay, and kaolin and about 600 billion tons of anorthocite. However, these reserves are almost uniformly of low quality, and there is little indication that they will be minable in the foreseeable future. Anaconda has experimented with extraction of aluminum from bauxite clays, but these experiments do not appear to have been successful.

In 1963, the last year for which Census data are available, the total number of employees in U.S. bauxite mining was 552, of which 414 were production workers. Almost all the employment was in Arkansas, and most of the employment in Arkansas was in Saline County.[1]

Bauxite mining in Arkansas (and in the United States) can probably be categorized as a declining industry. There is little evidence of capacity expansion or development of new deposits. For example, between 1958 and 1963 capital expenditures in bauxite production declined from $1.408 to $0.269 million, or only slightly more than 1 percent of the value of shipments in 1963 of $21.5 million. In 1967 it was estimated that bauxite deposits in Arkansas containing over 30

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[1] *Census of Mineral Industries*. (Department of Commerce, 1963), Vol. I, p. 10D-6 and Vol. II, pp. 4-9 and 4-10.

percent Al_2O_3 contained about 105 million tons of bauxite.[1] Under current conditions, however, a bauxite ore must contain at least 50 percent Al_2O_3 to be commercially minable. Thus it appears that reserves of commercial ore in Arkansas are limited.

An increase in the costs of production at the alumina and aluminum stages of production would probably have little effect on U.S. bauxite mining. Increases in production costs in bauxite mining itself could cause some bauxite facilities to be shut down. The employment and income effects of this on the U.S. economy would not be substantial, although the economies of Pulaski and Saline Counties would almost certainly be damaged.

Alumina

In 1969, total U.S. capacity for alumina production was 6.781 million long tons; imports in that year, primarily from Australia and Surinam, totalled 1.912 million long tons.[2] The locations, 1969 capacities, and reported 1970 employments of U.S. alumina plants are as follows:[3]

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[1] *Potential Sources of Aluminum.* Bureau of Mines, p. 10.

[2] *Minerals Yearbook* (1969), pp. 202, 205.

[3] *Ibid.*

	Capacity at end of 1969 (Thousands of Short Tons)[1]	1970 Employment (Number)[2]
Aluminum Company of America		
Bauxite, Ark.	400	NA
Mobile, Ala.	950	NA
Point Comfort, Tex.	900	NA
Total	2,250	NA
Harvey Aluminum, Inc.		
St. Croix, Virgin Islands	350	NA
Kaiser Aluminum and Chemical Corp.		
Baton Rouge, La.	985	850
Gramercy, La.	620	NA
Total	1,605	850
Ormet Corp.		
Burnside, La.	550	NA
Reynolds Metal Co.		
Hurrican Creek, Ark.	840	1,250
San Patricio, Tex.	1,186	950
Total	2,020	
Grand Total	6,781	

Thus, the only states with alumina production are Texas (2.086 million long tons); Louisiana (2.155 million long tons); Arkansas (1.240 million long tons) and Alabama (0.950 million long tons).

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[1] *Minerals Yearbook* (1969), pp. 202, 205.

[2] *Engineering and Mining Journal, International Directory of Mining and Mineral Processing Operations*, 1970.

The alumina plants in the United States tend to be quite old. The facilities in Mobile, Baton Rouge, and Hurricane Creek date back to World War II. The facilities at Bauxite and San Patricio were constructed in the early 1950's and the facilities at Point Comfort and Gramercy in the late 1950's. Harvey's plant in the Virgin Islands was completed in 1967. The capacities of some of the plants have been expanded over time, so not all the equipment at the plants is as old as the above data would indicate.

The principal pollution abatement problem at alumina facilities is water pollution. The costs of achieving water pollution abatement standards apparently vary substantially among the U.S. plants. The facilities at Baton Rouge and Gramercy reportedly have the most severe control problems.

There has been a clear trend during the past decade to construct alumina facilities at the bauxite source. Although operating costs in producing countries may be higher than in industrialized nations, this higher cost is offset by the substantial savings in transport costs if the alumina facilities are contiguous to the bauxite mines. In addition, there has been substantial pressure from the producing countries on the aluminum industry to construct alumina facilities in the same country in which bauxite is mined.

Aluminum

In 1970 total U.S. domestic primary aluminum ingot production was 7.592 million pounds; primary ingot imports

(primarily from Canada) were 0.700 million pounds and primary ingot exports (primarily to Europe and Japan) were 0.817 million pounds. The market value of this production was approximately $2 billion.

The available data on the location, capacities, employment, source of power, type of technology, and approximate dates of first production of all of the aluminum reduction plants in the U.S. is listed in Table 7-1. The plants are located in two broad areas: a cluster in the Pacific Northwest and a band from southeast Texas to northern New York State. Because of the availability of low-cost hydroelectric power, the aluminum companies have constructed 1.012 million tons of capacity in Washington, 0.191 million tons in Oregon, and 0.175 million tons in Montana. The smelters in Arkansas, Texas, and Louisiana are located in areas that are easily accessible to either U.S. or imported bauxite and to sources of natural gas. The remaining plants are largely located in the Tennessee Valley, the Ohio River Valley, and the St. Lawrence Seaway (upstate New York), all of which have relatively low power costs and ar near major industrial markets. The installed aluminum capacity by states at the end of 1970 was as follows:

Table 7-1

DATA ON ALUMINUM REDUCTION PLANTS IN THE U.S.

Operator	Situation of Plant	Annual Capacity at End of 1970 (Thousand Short Tons)	Date of First Operation	Principle Source of Power	1970 Employment	Smelter[1] Technology
Alcoa	Massena, N.Y.	125,000	pre-1946 1958	Hydro		PB
	Alcoa, Tenn.	200,000	pre-1946	Hydro		PB
	Badin, N.C.	100,000	pre-1946	Hydro		PB
	Vancouver, Wash.	100,000	pre-1946	Hydro		PB
	Point Comfort, Tex.	175,000	1950	Gas		VSS
	Wenatchee, Wash.	175,000	1952	Hydro		PB
	Rockdale, Tex.	275,000	1952	Gas		PB
	Evansville, Ind.	175,000	1960	Hydro		PB
		1,325,000				
Anaconda	Columbia Falls, Mont.	175,000	1955	Hydro		VSS
Consolidated	New Johnsonville, Tenn.	140,000	1971	Hydro		PB
Eastalco	Frederick, Md.	85,000	1970	Steam-electric		PB
Gulf Coast	Lake Charles, La.	35,000[2]	1971	NA		PB
Harvey	The Dalles, Ore.	91,000	1958	Hydro		VSS
Intalco	Bellingham, Wash.	260,000	1966	Hydro		PB
Kaiser	Tacoma, Wash.	81,000	pre-1946	Hydro	240	HSS
	Mead, Wash.	206,000	pre-1946	Hydro	1,700	PB
	Chalmette, La.	260,000	1951	Gas	2,564	HSS
	Ravenswood, W.Va.	163,000	1957	Coal		PB
		710,000				
National-Southwire	Hawesville, Ken.	180,000	1969	NA		PB
Noranda	New Madrid, Mo.	70,000[2]		NA		PB
Ormet	Hannibal, Ohio	220,000	1958	Coal		PB
Revere	Scottsboro, Ala.	112,000		NA		PB
Reynolds	Jones Mills, Ark.	122,000	pre-1946	NA	940	PB
	Listerhill, Ala.	221,000	pre-1946 1958	Hydro		HSS
	Longview, Wash.	190,000	pre-1946	Hydro	900	HSS
	Troutdale, Ore.	100,000	pre-1946	Hydro		PB
	San Patricio, Tex.	111,000	1952	NA	890	HSS
	Arkadelphia, Ark.	63,000	1952	NA	500	HSS
	Massena, N.Y.	128,000	1959	Hydro		HSS
		935,000				
	TOTAL	4,121,000				

[1] PB = Prebaked HSS = Horizontal Soderboy System
VSS = Vertical Soderboy System

[2] Under construction at the end of 1970.

Table 7-1 (continued)

Source for preceding table: *Minerals Yearbook*, 1947-1969; American Bureau of Metal Statistics, *1970 Yearbook*; *Engineering and Mining Journal*, International Directory of Mining and *Mineral Processing Operators*, 1970.

INSTALLED ALUMINUM CAPACITY

	Thousands of Short Tons
Pacific Northwest	
Washington	1,012
Oregon	191
West	
Montana	175
Midwest	
New York	253
Indiana	175
Ohio	220
South and Southwest	
Tennessee	340
North Carolina	100
Texas	561
Maryland	85
Louisiana	260
West Virginia	163
Kentucky	180
Arkansas	185
Alabama	221
TOTAL	4,121

Smelters using the horizontal spike Soderberg technology apparently face the highest cost of meeting air pollution abatement standards. The smelters of the following locations use this technology:

Tacoma, Washington	Kaiser
Chalmette, Louisiana	Kaiser
Listerhill, Alabama	Reynolds
Longview, Washington	Reynolds
San Patricio, Texas	Reynolds
Arkadelphia, Arkansas	Reynolds
Massena, New York	Reynolds

As Table 7-1 indicates a number of smelters in the United States are many decades old and may be nearing the end of their economic lives. The smelters at the following sites were all constructed before or during World War II;

Massena, New York	Alcoa
Alcoa, Tennessee	Alcoa
Badin, North Carolina	Alcoa
Vancouver, Washington	Alcoa
Tacoma, Washington	Kaiser
Meade, Washington	Kaiser
Jones Mills, Arkansas	Reynolds
Listerhill, Alabama	Reynolds
Longview, Washington	Reynolds
Troutdale, Oregon	Reynolds

Recent employment and production statistics of the primary aluminum industry are as follows:

	All Employees	Production Workers	U.S. Aluminum Production (Short Tons)
May 1971	30,600	25,000	341,797
Average 1970	30,900	25,200	3,976,148 (Total)

The number of employees per 1,000 tons of output is as follows:

	All Employees	Production Workers
May 1971 (Annual rate)	7.460	6.095
Average 1970	7.772	6.338

Because of disclosure problems, the only comprehensive regional data that exist on production and employment are data on employment rates by state. According to these data, employment rates in primary aluminum by states in 1967 were as follows:

State	Number of Employees
New York	1,000-2,499
Ohio	1,000-2,499
Indiana	500-999
West Virginia	1,000-2,499
North Carolina	500-999
Tennessee	1,000-2,499
Alabama	1,000-2,499
Arkansas	1,000-2,499
Louisiana	>2,500
Texas	>2,500
Montana	500-999
Washington	>2,500
Oregon	1,000-2,499

Balance of Payments in Aluminum

The United States is currently a net exporter of aluminum products through the semi-fabricated stage; in 1970 total exports were 637.8 thousand tons while total imports were 489.8 thousand tons. In 1969 a total of 591.6 thousand tons were exported, valued at $341.7 million, while a total of 561.3 thousand tons were imported, valued at $272.7 million. As the following data indicate, by far the largest percentage of this trade is in the form of primary aluminum ingot:[1]

1969 Exports	Quantity (Thousand Tons)	Value (Million Dollars)
Ingot, slab and crude	344.4	$172.1
Scrap	86.3	33.8
Plates, sheets, bars, etc.	135.7	99.6
Castings and forgings	4.4	10.5
Semifabricated forms, n.e.c.	4.1	7.7
Foil and leaf	5.3	8.5
Powder and paste	1.3	1.5
Wire and cable	10.1	7.9
TOTAL	591.6	$341.7
1969 Imports		
Metals and alloys, crude	468.2	$214.8
Circles and disks	7.0	4.6
Plates, sheets, etc., n.e.c.	57.6	24.3
Rods and bars	12.6	9.6
Pipes, tubes, etc.	3.5	3.5
Scrap	28.9	11.0
Foil	1.9	3.4
Flakes and powders	0.8	0.6
Wire	0.8	0.8
TOTAL	561.3	$272.7

[1] *Minerals Yearbook, 1969*, pp. 159-161.

The balance-of-payments surplus in aluminum, however, is offset by a balance-of-payments deficit in bauxite and alumina. In 1969 the United States imported 12,180 thousand long tons of bauxite, valued at $165.8 million, and imported 1,912 short tons of alumina, valued at $106.3 million.

U.S. imports of aluminum ingot come primarily from Canada; a substantial percentage of these imports represent shipments of ingot by Alcan to its own fabricating subsidiaries in the United States. Ingot imports grew gradually from 177 thousand tons in 1950 to a peak of 686 thousand tons in 1968 and then fell to 350 thousand tons in 1970. The ratio of ingot imports to total domestic supply has shown no significant trend; in fact, their share of the U.S. market fell from about 12 percent in 1950 to under 7 percent in 1970.

Foreign producers have in the past exercised considerable restraint in exporting aluminum to the United States and have not attempted to substantially increase their market share, even in times of substantial overcapacity. Part of this restraint is reportedly attributable to a fear that the U.S. government will increase tariffs if U.S. imports increase significantly. Accordingly, we would not expect a substantial increase in ingot imports if U.S. production costs increase by $0.01 or $0.02 a pound (without an increase in U.S. trade barriers).

Financial Data of Aluminum Companies

Table 7-2 presents relevant financial data on all of the firms which have interests in U.S. smelters (with the

exception of Southwire Company, which is partly owned by National Steel). As the data show, without exception the producing firms are all large by almost any standards. In 1970 the combined after-tax earnings of the four U.S. firms primarily engaged in aluminum production (Alcoa, Kaiser, Reynolds, and Harvey) were over $200 million. The combined values stockholder's equity and total assets of these four firms were $2.715 billion and $6.402 billion dollars, respectively and the combined capital expenditures were $519 million. The two foreign aluminum producers having interests in U.S. aluminum smelters, Péchiney and Alussuise, are also large firms. In 1970 the net incomes of these two firms were $139 and $129 million, respectively. Finally, none of the remaining U.S. firms which have interests in aluminum smelters can be described as small or "sick" firms.

It should be pointed out, however, that in recent years the profit rates of the major producers have been several percentage points lower than the profit rates of other nonferr-us metals industries and of durable manufacturing in general. This poor record is attributable in part to over-expansion of capacity, a problem that has plagued the industry for most of the period since 1958.

Until 1958, Alcoa's profit rate had been almost consistently above 10 percent throughout its corporate history. Alcoa's profit rate fell sharply in 1958 to 6.24 percent and remained at levels of 6 to 8 percent until 1965. This decline in profits can probably be attributed to a disastrous over-expansion in capacity constructed by Alcoa and the other major firms in the mid-1950's. By 1966 the profit rate had recovered to 10.8 percent and it remained at approximately this level through 1969.

The profit histories since the Korean War of the other major aluminum producers are quite similar to that of Alcoa, although in earlier years Reynolds tended to do better than Alcoa and in more recent years Kaiser has also done better than Alcoa. Anaconda, which is primarily a copper producer, has had lower profits than the aluminum producers fairly consistently.

The year 1971 is a record poor year for the aluminum industry, and reported earnings through the first three quarters of 1971 are sharply lower than 1970 earnings over the same period. For example, Alcoa's earnings fell from $18.1 million in the third quarter of 1970 to $4.1 million in the third quarter in 1971. Over the same period Reynold's earnings fell from a profit of $8.5 million to a low of $5.0 million and Kaiser's earnings fell from a profit of $7.5 million to a low of $5.5 million. The industry will eventually recover from the current weak market conditions caused by the simultaneous occurrence of an economic recession and an increase in production capacity, but earnings probably won't recover to normal levels until 1973 or 1974.

Although the profit record of the aluminum producers has been relatively poor in recent years, the financial resources of these firms are immense in absolute terms and the industry should be able to finance the investment costs of the projected pollution abatement facilities. Of course if these investments are as large as the estimates presented later in this report they will probably result in a significant decline in the already low profit rates of these firms.

Table 7-2

FINANCIAL DATA ON U.S.

ALUMINUM SMELTING OPERATIONS

(thousands of dollars)

Company	Net Income	Stockholder's Equity	Total Assets	Capital Expenditures	Profit Rate
Alcoa					
1970	95,459	1,249,007	2,628,192	284,887	7.64%
1969	122,376	1,194,529	2,428,466	247,324	10.24
Anaconda					
1970	63,787	1,188,375	1,784,657	90,500	5.37
1969	99,313[1]	1,166,172	1,763,676	127,016	8.32
Harvey					
1970	9,658	147,512	307,101	34,370	6.55
1969	15,395	144,791	277,740	10,234	10.63
Intalco					
Howmet[2] (50%)					
1970	13,670	99,436	363,018	48,139	13.75
1969	16,288	105,484	325,415	70,349[3]	15.44
Amax (50%)					
1970	83,600	609,700	1,066,770	110,201	13.71
1969	69,090	553,100	940,920	192,710	12.49
Kaiser					
1970	50,761	629,009	1,625,934	87,156	8.07
1969	68,511	587,625	1,457,262	99,215	11.66
Norandа[4]					
1970	58,222	412,330	871,319	94,925	14.12
1969	54,183	380,870	824,520	69,848	14.23
Ormet					
Olin Corp. (50%)					
1970	566	596,288	1,134,739	89,968	.09
1969	50,342	612,883	1,078,108	76,724	5.22

Table continued on following page.

CHARLES RIVER ASSOCIATES INCORPORATED

Table 7-2 (continued)
FINANCIAL DATA ON U.S.
ALUMINUM SMELTING OPERATIONS
(thousands of dollars)

Company	Net Income	Stockholder's Equity	Total Assets	Capital Expenditures	Profit Rate
Revere (50%) (see Revere)					
Revere Copper & Brass					
1970	9,087	159,541	430,529	90,308[5]	5.70%
1969	12,135	157,278	412.409	67,583[5]	7.72
Reynolds Metals Co.					
1970	46,134	689,618	1,840,521	112,670	6.69
1969	55,088	658,316	1,780,625	128,600	8.37
Consolidated Aluminum Co Phelps Dodge (40%)					
1970	112,621	656,219	898,494	94,021[6]	17.16
1969	89,435	558,286	811,426	106,197[6]	16.02
Aluisse (60%) (see Gulf Coast)					
Eastalco Pechiney Compagnie[7]					
1970	138,600	2,352,496[8]	4,046,127	1,117[9]	5.89
1969	110,952	2,298,126	3,611,766	898[9]	4.83
Gulf Coast Aluminum Co. Aluisse (100%)[10]					
1970	129,300	1,715,200	3,938,400	548,600[11]	7.54
1969	117,400	1,625,800	3,585,900	455,300[11]	
National-Southwire Alum. Co. National Stee (50%)					
1970	59,024	1,867,615	872,341	151,010	3.76
1969	78,015	1,454,428	851,545	137,162	5.36

Table continued on following page

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Table 7-2 (continued)
FINANCIAL DATA ON U.S.
ALUMINUM SMELTING OPERATIONS
(thousands of dollars)

Southwire Co. (50%)
No information available
25% owned by National Steel

Footnotes:

[1]After additional Chilean participation in profits of $51,937,000.

[2]Howmet = combined operations of old Howmet (excluding Howmedica) with the aluminum operations of Péchiney Aluminum Corp. Name of combined operations = Howmet.)

[3]Figures = additions to Eastalco plant and other additions to property plus start-up costs at Eastalco plus development costs on aerospace contract.

[4]Canadian dollars.

[5]Net additions to property, plant, and equipment.

[6]Figures exclude pre-operating mining developments.

[7]Figures in thousands of French francs.

[8]Figures = additions to fixed and other assets.

[9]Figures = capital stock (stock + reserves)

[10]Figures in thousands of Swiss francs.

[11]Figures = application of funds: investment.

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This is one of four reports prepared by
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Copper
Lead
Zinc